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Correlating maintenance, energy efficiency and fuel poverty for traditional buildings in the UK

A scoping study funded by Cadw, Historic Environment Scotland and Historic England

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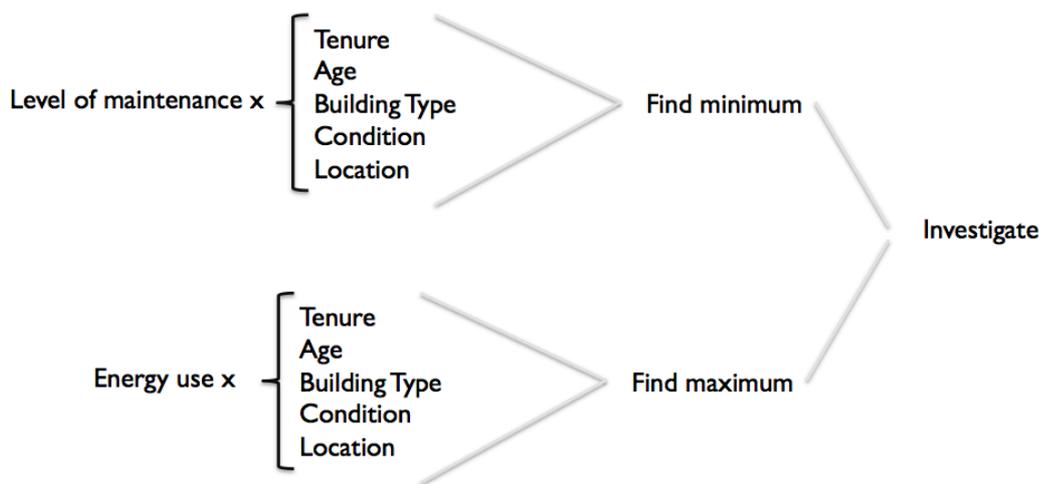
I. Introduction

The scoping study here reviews potential for developing a research framework to address the feasibility for energy efficiency of historic buildings to be increased through better maintenance programmes. The new British Standard for conservation has already triggered recognition of the correlation of dampness to energy efficiency (BSI, 2013), here we aim to address further means to link building condition to building performance and to further substantiate that claim. More broadly the paper investigates the potential for recovering evidence in the interests of incentivising maintenance as a business case addressed to stakeholders and custodians, underwriters and legislators.

The climate change agenda that drives the need to increase energy efficiency poses challenges to the perceived performance of historic building stock as assimilated through energy ratings. The depiction of traditional buildings as poorly performing incentivises energy retrofits. It has already been established that baseline scenarios require revision based on in situ measures of thermal performance (BRE, 2015). Other research highlights the risks to historic built fabric that emerge from ill-conceived retrofit measures (Fouseki and Cassar, 2014). Both methods used for summarising the physical thermal performance of traditional built fabric as well as presumptions of occupant use and behaviour can risk leading to prejudicial conclusions and erroneous decisions.

Alternative lines of inquiry, based upon in-situ monitoring, research which examines behavioural responses to retrofit and work which monitors energy consumption as opposed to supposed energy consumption each address potential concerns for the adoption of these assumptions. The question of how to promote the case for maintenance, as opposed to retrofit measures as a first line of action relevant to energy efficiency, is addressed here.

The aim of this exercise is to quantify the areas of greatest need and impact through the correlation of available data as illustrated here:



2. Executive summary

Key findings

Overall quantities

- Pre-1919 building stock in England is 90% domestic.
- In both England and Wales terraced housing is the dominant pre-1919 domestic typology, whereas in Scotland it is tenements.
- In all nations owner-occupier is the most common tenure for these.
- Social housing represents a very small percentage of historic dwellings in England, Wales and Scotland.
- Energy performance is an area lacking measured as opposed to assumed data.

Condition

- In Scotland the need for urgent or critical repair reduced with age, with the pre-1919 stock having the highest percentage requiring attention.
- The private rented sector presented the highest percentage of dwellings in disrepair in Scotland.
- In England and Wales pre-1919 terraced houses are the most affected by penetrating or rising damp.
- In Scotland damp is more evenly spread across the housing stock and its age. The largest group with disrepair to critical elements is post-1964 dwellings which are owner-occupied.
- In both England and Wales, pre-1919 terraced houses are the largest group in a state of disrepair. 72% in Wales are owner-occupied and 46% in England, 51% are social sector and 3% privately rented.
- Historic England reports that the cost of repairing buildings that have become at risk is increasing with regard to conservation deficits noted in the Heritage at Risk Register.
- In Wales, properties in rural locations are more likely to be at risk than their urban counterparts and the Swansea Bay area has the highest concentration of at risk and vulnerable listed buildings.

Recommendations

- It is critical to undertake in situ u-value measurements and pressure tests of a large sample of historic dwellings to correlate age, condition and building typology against energy use.
- Review energy performance of buildings that are part of proactive maintenance schemes in comparison to buildings only receiving reactive maintenance. This could include in situ monitoring, pressure testing and the review of utility bills.
- Better standardisation of data for fuel poverty across devolved nations to enable better correlation to building age and condition.
- Deeper consideration and data correlating broader health and well-being costs of buildings in disrepair is required.
- Correlations of 'Rebound Effect' to retrofit could be compared to programmes based on increased maintenance.

- Use the existing EU-funded iSERVcmb project to apply existing energy consumption data from other estates and incorporate aspects such as age and condition to develop new benchmarks.
- The business viability of maintenance programmes and financial incentives should be analysed.
- The efficacy of legal threats for property care and insurance clauses in persuading people to act requires monitoring.
- The potential to engage the insurance industry in research seeking evidence for the efficacy of preventative action for risk engineering should be pursued in the context of climate change-related claims.
- The geographical correlation between GDP and historic buildings at risk should be made more clear.
- The potential for co-ownership schemes which champion maintenance internationally should be evaluated in the context of collectively inhabited but not co-owned structures such as terraced houses in the UK.
- The viability of heritage accreditation and hallmark schemes which extend into industry and products in France should be re-imagined in the UK.
- It is important to examine the potential value of this work to wider stakeholders such as health, property and insurance organisations. It is equally important to consider the potential of incorporating the data resources which have recorded perceived levels of phenomena, such as urban degradation related to perceived crime risk or health related data which may be related to poor levels of building maintenance.

3. Defining maintenance

The concept of maintenance is one of the key principles of building conservation as captured by William Morris in the founding manifesto for the Society for the Protection of Ancient Buildings (SPAB) ‘... to stave off decay with daily care...’ (Morris, 1877). This is reinforced by the British Standard “Guide for Conservation of Historic Buildings”, BS 7913:2013, which states: “Maintenance is the continuous care of a historic building and is the most common and important activity in their conservation and preservation” (BSI, 2013). A similar sentiment was expressed by the now superseded Planning Policy Guidance PPG15 “Planning and the Historic Environment”, which stated: “Regular maintenance and repair are the key to the preservation of historic buildings. Modest expenditure on repairs keeps a building weather tight, and routine maintenance (especially roof repairs and regular clearance of gutters and down pipes) can prevent much more expensive work becoming necessary at a later date . . . Regular inspection is invaluable” (Department for Communities and Local Government., 1994). However, the current National Planning Policy Framework offers no such guidance (DCLG, 2012).

The Council of Europe’s Convention of Granada (1985) signed by the UK, placed financial responsibility for Europe’s architectural heritage with the individual countries, with the following responsibilities:

“-To provide financial support by the public authorities for maintaining and restoring the architectural heritage on its territory, in accordance with the national, regional and local competence and within the limitations of the budgets available.
- To resort, if necessary, to fiscal measures to facilitate the conservation of this heritage.
- To encounter private initiatives for maintaining and restoring the architectural heritage” (Council of Europe, 1985).

Historic England defines *maintenance* as: “Routine work regularly necessary to keep the fabric of a place in good order”(Historic England, 2008), as distinguished from *period renewal* which they define as “comprehensive dismantling and replacement of an element of a place, in the case of structures normally reincorporating sound units” (Historic England, 2008). This in turn differs from *repair*, which is “work beyond the scope of maintenance to remedy defects caused by decay, damage or use, including minor adaptation to achieve a sustainable outcome, but not involving restoration or alteration” (Historic England, 2008). Whereas *restoration* is “to return a place to a known earlier state, on the basis of compelling evidence, without conjecture” (Historic England, 2008). Historic Environment Scotland notes that “...it is often the case that repair and maintenance will be carried out at the same time...” (Historic Scotland, 2007) and states that “the primary purpose of repair is to restrain the process of decay without damaging the character of the buildings or monuments, altering the features which give them their historic or architectural importance, or unnecessarily disturbing or destroying historic fabric” (Historic Scotland, 2007). They also highlight the importance of regular maintenance as “...frequently, the decay and deterioration of historic fabric can be directly attributed to inadequate design and/or lack of maintenance” (Historic Scotland, 2007). Specific problems can also be avoided by maintaining the building such as the decay of built-in joists and beams in damp masonry walls which occurs “usually as a result of inadequate maintenance” (Historic Scotland, 2007).

4. Building stock data

There exists a variety of possible sources of both quantitative and qualitative data for reviewing the domestic and non-domestic building stock in England, Wales and Scotland. The work undertaken in 2014 by Historic Scotland as part of the European EFFESUS (Energy Efficiency for EU Historic Districts Sustainability) project (Hay et al., 2014) sets out a clear overview of many of these sources. This information has been expanded by the research undertaken for this report and a summary of useful sources is presented.

The EFFESUS project was a European-wide project looking at the energy use of historic buildings, defined by the project as pre-1945. The project proposes a methodology for the categorization of historic building stock. However, only a pilot in Visby, Sweden appears to have been undertaken as part of the project. In general the project did not focus on the condition of the building stock, except for the BETSI (Building's Energy Technical Status and Indoor Environment) 2006, a Swedish project that looked at the quality of the indoor environment of a 1800 representative sample of the Swedish building stock. A particular emphasis was placed on the building condition and lack of maintenance (Frick et al., 2013). Other potential datasets include UCL's "Home Front" evaluation of the Government's "Warm Front" scheme, UCL's Carbon Reduction in Buildings project (CaRB) and the Energy Savings Trust's HEED (Home Energy Efficient Design) programme.

	Source	Coverage	Limitations
Listed Building Data	British Listed Buildings Online	Listed buildings in England, Scotland and Wales	Only includes listed buildings. Not all entries are for buildings and some entries cover multiple buildings. Quality of building description varies according to listing officer. Condition of property is only recorded at date of listing and not updated.
	National Heritage List for England	Approximately 500,000 listed buildings in England	
	Historic Environment for Scotland's Designations list	55,898 designated entries of listed sites in Scotland of which 85% are buildings.	
	"Historic Wales" and "Coflein"	Records of the Royal Commission on the Ancient and Historic Monuments of Wales, Cadw, the four Welsh Archaeological Trusts and Amgueddfa Cymru (National Museum)	Not all entries are buildings. Some entries cover multiple buildings and some buildings appear more than once depending on data available e.g. listing description, photographs, plans etc.
	Heritage Gateway	A resource of Historic	As with Coflein it

		England, the IHBC and the Association of Local Government Archaeological Officers (ALGAO). Covers designated and non-designated heritage assets.	contains a wide variety of types of information. Drawing from many different databases there is much repetition.
Historic maps	Edina Digimaps Historic Roam	Scanned historic Ordnance Survey maps. Allows reasonably accurate construction dates for buildings by comparing sequential maps.	Not all areas covered equally. Gaps between the publication of map revisions varies.
Housing Surveys	English Housing Survey	A sample of English domestic building stock. The last available full dataset is for 2012 and covers 12,763 homes, approximately 0.05% of the housing stock.	Limited samples. They do however include data on age and type of property, tenure, current condition and energy efficiency. It should be noted that building age is based on the opinion of occupant and/or interviewer and that the energy efficiency uses SAP and does not take into account the buildings condition.
	Living in Wales Property Survey	A sample of Welsh domestic building stock. The last available full dataset is for 2008 and covers 2,741 homes, approximately 0.2% of the housing stock.	
	Scottish Housing Condition Survey	A sample of the Scottish domestic building stock. The last available full dataset is for 2013 and covers 8,731 homes, approximately 0.3% of the housing stock.	
	Bridgend County Borough Council, Private Sector House Stock Condition Survey	A sample of private sector domestic stock in Bridgend County, South Wales. The survey was undertaken in 2009 and covered 1,199 dwellings, approximately 2.3% of the private housing stock.	

	UK Housing Review 2015	A compendium of current financial and statistical data on the UK domestic building stock.	Overlaps with Housing Condition Surveys. Full dataset is not available thereby preventing full correlation of data.
	Energy and Environment Prediction (EEP) model.	Researchers at the Welsh School of Architecture (WSA), Cardiff University have used algorithms to predict a buildings age by its footprint.	Pilot study had an accuracy of 60% with pre-1919 buildings being easier to identify with 69% accuracy.
Non-domestic building stock data	Valuation Office Agency (VOA), Inland Revenue	Holds information on "hereditaments", pieces of floor space or land with a single occupant or landlord. All rateable property in England and Wales. Covers Council Tax (domestic) and non-domestic rates.	Detailed data must be requested from VOA. It would appear that data on age and condition of property is not usually made public. Data has been requested for this report but has not been made available to date.
	Scottish Assessors Association (SAA)	The SAA Portal provides all Scotland Valuation Rolls & Council Tax Lists online.	The valuation role can be searched online, however the full document must be requested. It was not possible to ascertain the detail of the roll.
	The Geoinformation Group	Private company providing geographic information	Work at UCL has queried the accuracy of some of their classification of building age.
	Non-domestic Building Energy Fact File	A BRE publication funded by the Department of the Environment, Transport and the Regions, looking at energy use in the non-domestic building	Published 18 years ago. No information on building condition.

		stock in 1998. Includes data on age of stock.	
	Non-domestic Building Stock Database Project	A project funded by the then Department of Environment, Food and Rural Affairs using data provided by the Valuations Office of the Inland Revenue. The project aimed to correlate age, form, use and energy efficiency of non-domestic buildings in the UK.	Has not recently been updated. A team at UCL are currently working on a 3D model of the non-domestic building stock of England and Wales. Currently no data on age is attached to this but there is an ongoing project studying building age and energy use in Camden.
Buildings at Risk Registers	Historic England, Heritage at Risk programme	A searchable database of Grade I and II* properties at risk, including information on current condition. Regional lists also available for download.	Overlaps with listed building data but includes information on current condition. Only includes those where condition is critical. Limited information available.
	Buildings at Risk Register for Scotland	A searchable database of heritage assets at risk, including information on current condition.	Overlaps with listed building data but includes information on current condition. More information provided than English counterpart.
	The condition of listed buildings in Wales	Annual reports on condition of Welsh listed buildings. (Last available version 2013)	Only an overview is available online with no specific information on individual properties. However it is noted that the survey contains greater levels of data available to Cadw.

Energy Performance Certificates	Domestic Energy Performance Certificate Register	Searchable database of domestic energy performance certificates for the UK.	Since January 2013 listed buildings are exempt from requiring EPCs. For domestic properties EPCs are required only at the point of selling or letting the property. Searchable only dwelling by dwelling, full datasets can however be purchased.
	Non-domestic Energy Performance Certificate Register	As above but for non-domestic properties	As above
	Display Energy Certificate Data	Measured energy use data for all buildings in England and Wales, occupied by a public authority, where the total useful floor area of the building exceeds 250m ² , and which are frequently visited by the public. The publically available dataset includes date of construction, floor area and use.	Of the 8062 entries on the data set published in December 2015, only 17% have energy (DEC) information provided and only 10% both DEC and known construction date.
Sector specific	The Justice Estate's Energy Use	A report on the energy use of the built estate of Her Majesty's Court Service. Includes age of building stock.	Very specific in its scope. However, similar data may exist for other sectors and organizations with large estates.
	A Survey of Energy Use in Museums and Galleries	A survey of the energy use of 100 museum buildings in the UK	Published in 1994 so now 22 years out of date. Research to identify how these 100 buildings have changed may provide interesting results.

	iSERV CA Cardiff University	Energy monitoring of entire university estate using smart metering.	Currently no data on building age or condition, however this would be relatively easy to obtain.
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Table 1. Available sources of quantitative and qualitative data on the English, Welsh and Scottish building stock (Hay et al., 2014, Historic England, 2016, Historic Environment Scotland, 2016b, British Listed Buildings Online, 2016, Department for Communities and Local Government, 2013, The Local Government Data Unit - Wales, 2010, Scottish Housing Condition Survey Project Team, 2014, Fordham Research, 2009, Pout et al., 1998, Bruhns, 2000, Wallsgrove, 2008)

There follows a review of the initial results and conclusions that can be drawn from some of these key sources of available data.

Listed building data

The designation lists of England, Wales and Scotland are a useful source of data for historic buildings. Whilst not all listed buildings are historic (pre-1919) and not all historic buildings are listed, some broad assumptions can be made. Historic England states: "All buildings built before 1700 which survive in anything like their original condition are listed, as are most of those built between 1700 and 1840. Particularly careful selection is required for buildings from the period after 1945. Usually a building has to be over 30 years old to be eligible for listing" (Historic England, 2016). Therefore a large proportion of the older (pre-1840) building stock is likely to be listed but an unknown proportion of post-1840 pre-1919 building stock may not be. Further research should be undertaken to establish an approximation of the number of unlisted pre-1919 properties.

In general the designation lists contain reasonably detailed information regarding the listed building stock, including approximate age, building use (at time of listing) and construction materials. The quality of the descriptions however varies dramatically depending on the listing officer responsible for the designation and the significance of the building in question. Even with these limitations the designation lists have a huge amount of useful data that can be analysed. An example of this can be seen in the distribution of historic timber-framed buildings in England and Wales (Figure 1).

Listed buildings in England

It is estimated by Historic England that there are around 500,000 listed buildings in England. The exact figure is not known as a list entry may refer to multiple buildings. In March 2015 the total number of listed building entries was 376,099, of these 97% are pre-1900 (Historic England, 2016). 2.5% of listed buildings in England are Grade I, 5.5% Grade II* and 92% are Grade II (Historic England, 2016). Historic England's website <https://www.historicengland.org.uk/listing/the-list/> allows detailed searches, however for the production of larger datasets it is best to contact Historic England directly.

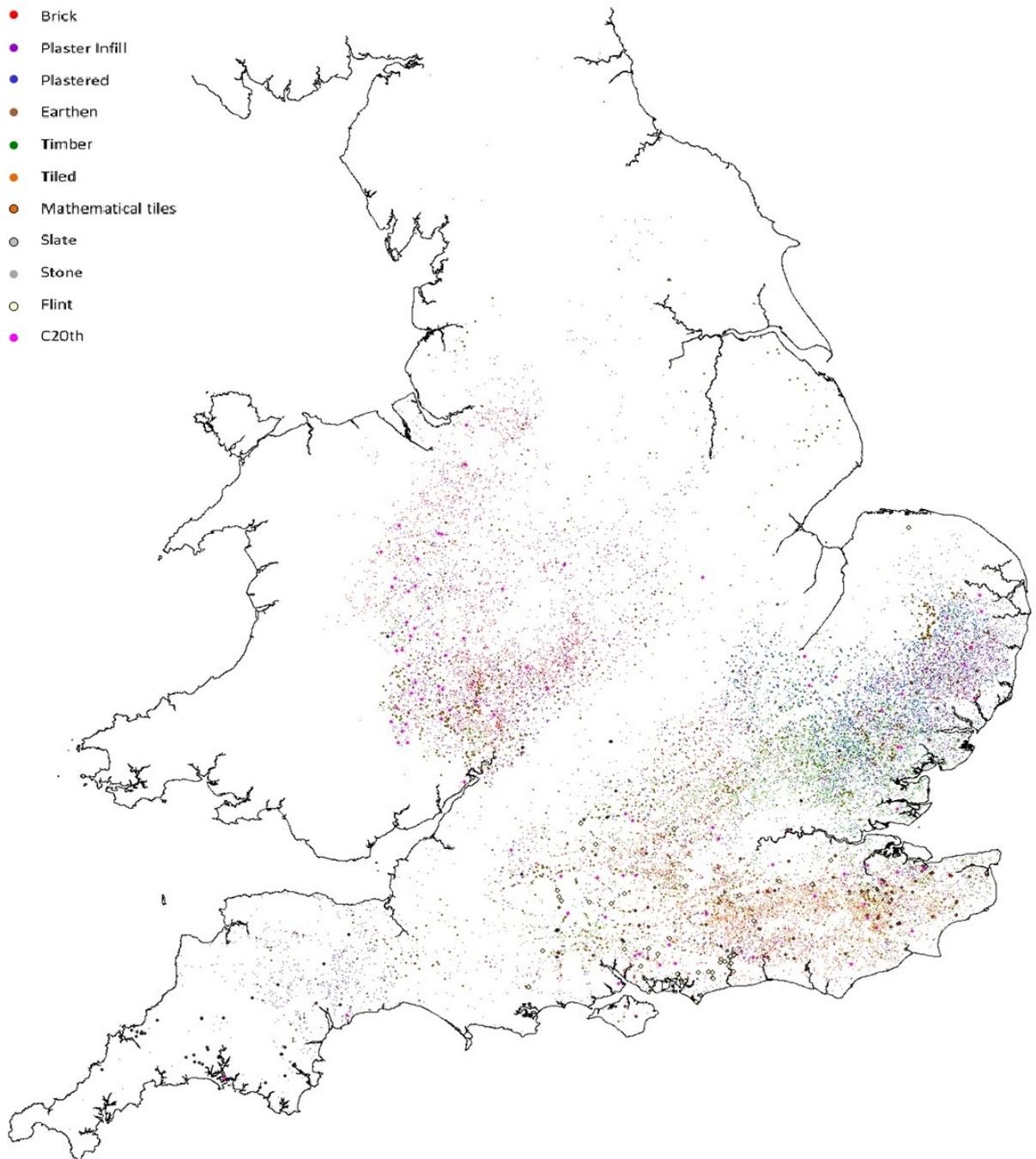


Figure 1. Distribution of historic (pre-1850) timber-framed buildings in England and Wales.
©Christopher J. Whitman. Coastline © Crown Copyright and Database Right [2016]

Listed buildings in Wales

A survey of all communities in Wales was completed in 2005 which resulted in 30,000 buildings being listed (Cadw, 2016). The websites "Historic Wales" <http://historicwales.gov.uk/> and "Coflein" www.coflein.gov.uk both have a wealth of information that can readily be searched for specific buildings or specific areas. Both however have limitations when wishing to look at the overall picture or produce datasets for further analysis. It may therefore be better to request a dataset directly from Cadw.

Listed buildings in Scotland

In Scotland there are 55,898 designation entries of which 47,291 are buildings, accounting for 85% of the designations. Of these 7.5% are Category A, 50% are

Category B and the remaining 42.5% Category C (Historic Environment Scotland, 2016b). Historic Environment Scotland's website <http://portal.historic-scotland.gov.uk/designations#> allows for searches defined by category and geographical location. This would allow for more detailed analysis in the future of the distribution of Scotland's listed buildings. The results of searches can be downloaded as CSV files.

Historic maps

Edina Digimaps, Historic roam

The University of Edinburgh's Edina Digimap service offers online access to scanned historic Ordnance Survey maps. Comparison of sequential versions of the maps can allow a reasonably accurate dating of buildings. The coverage of areas is not always consistent and the period between each publication is not constant. They do however provide a very valuable resource for verifying the approximate construction dates of the building stock as can be seen from the example below for the Bute Building, Cardiff. The building does not appear on the 1901 map (Figure 2 left) but does on the 1922 map (Figure 2 right). The building was in fact constructed between 1913 and 1916.

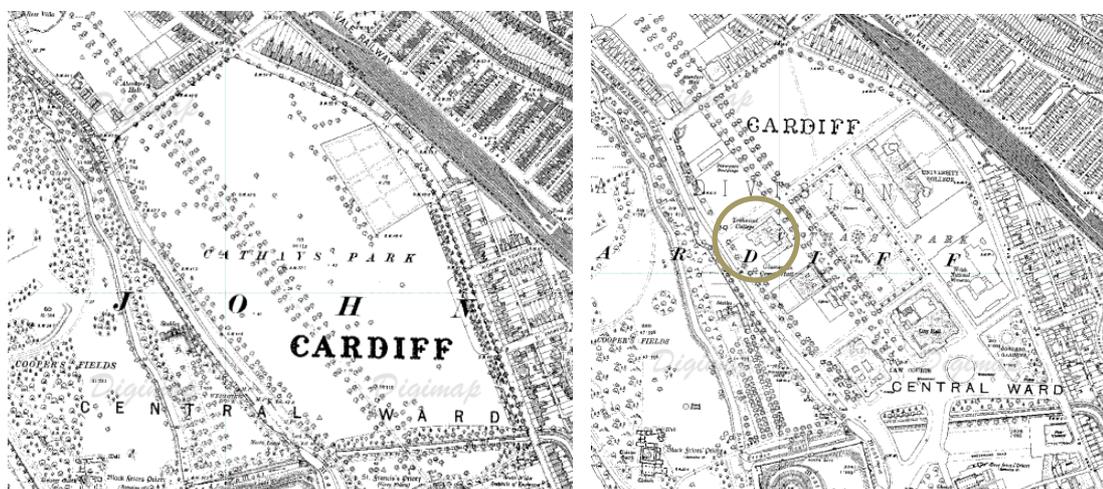


Figure 2. Left Cathays Park 1901 © Edinburgh University and right Cathays Park 1922 © Crown Copyright and Database Right [2016]. Shows the construction of the Bute Building (circled) occurred between 1901-1922

5. Domestic building stock data

In general there is more detailed information regarding the age and condition of the domestic stock than there is regarding the non-domestic stock, with the governments of all home nations gathering data on the former but not the latter. Both England and Scotland have reports published 2014 and comprehensive datasets from 2013 covering the age, type and condition of their national dwelling stock. In the case of Wales the last report published on a national housing survey was completed in 1998 and published in 2001. There was however a housing condition survey undertaken in 2008 as part of the Living in Wales Survey. Datasets from this survey are available through the UK Data Service. In all cases the data is based on a survey of a relatively small sample of the overall national stock. The last published review of the entire UK dwelling stock appears to have been in 2000 (Revell and Leather, 2000).

For all surveys it should be noted that the age of the building is based on an estimate by the householder, the interviewer or surveyor and not on accurate historic data. There is

therefore a margin of error with these estimates with approximate ages being rounded up or down to nearest decade or completely misjudged.

The energy efficiency data included in these surveys is equally flawed being based on SAP (Standard Assessment Procedure) calculations and not measured energy use. This does not therefore reflect the current condition of the building nor truly reflect the building's construction. SAP calculations require the input of the thermal conductivity of the walls (u-values) which have been shown to vary widely for historic and traditional constructions, often outperforming those stated by the British Standard (Rye and Hubbard, 2012, Rye et al., 2010, Baker, 2011). The airtightness of historic and traditional buildings is another variable that is assumed rather than measured and often misjudged (STBA, 2012). The latest research on the energy modelling of historic buildings published by the United States Department of the Interior, National Parks Service, National Centre for Preservation Technology and Training suggests that in order to obtain reliable results, in situ u-value monitoring and pressure testing should be undertaken and these values used for the simulation (Chung, 2016). It is therefore critical to undertake in situ u-value measurements and pressure tests of a large sample of historic dwellings to truly be able to correlate age, condition and building typology.

Figure 3 shows the age of the UK dwelling stock (not including Northern Ireland) based on the latest published data for each nation. Wales has the highest percentage of pre-1919 stock with 28% built before that date (The Local Government Data Unit - Wales, 2010). England (Department for Communities and Local Government, 2015a) and Scotland (DHRW, 2015) both have 20% pre-1919 and Scotland has the highest percentage of dwellings built post-1964 at 47%.

Figure 4 shows the composition of pre-1919 housing stock for each nation according to typology. In both England and Wales terraced housing is the dominant typology, whereas in Scotland it is tenements.

Figure 5 shows the composition of pre-1919 housing stock for each nation according to tenure. In all nations owner-occupier is the most common tenure. It would appear that Wales is the nation with the highest ownership. It should however be noted that the data for Wales is 8 years out of date and that private renting has increased in both England and Scotland over this period. Social housing would appear to represent a very small percentage of historic dwellings in England, Wales and Scotland.

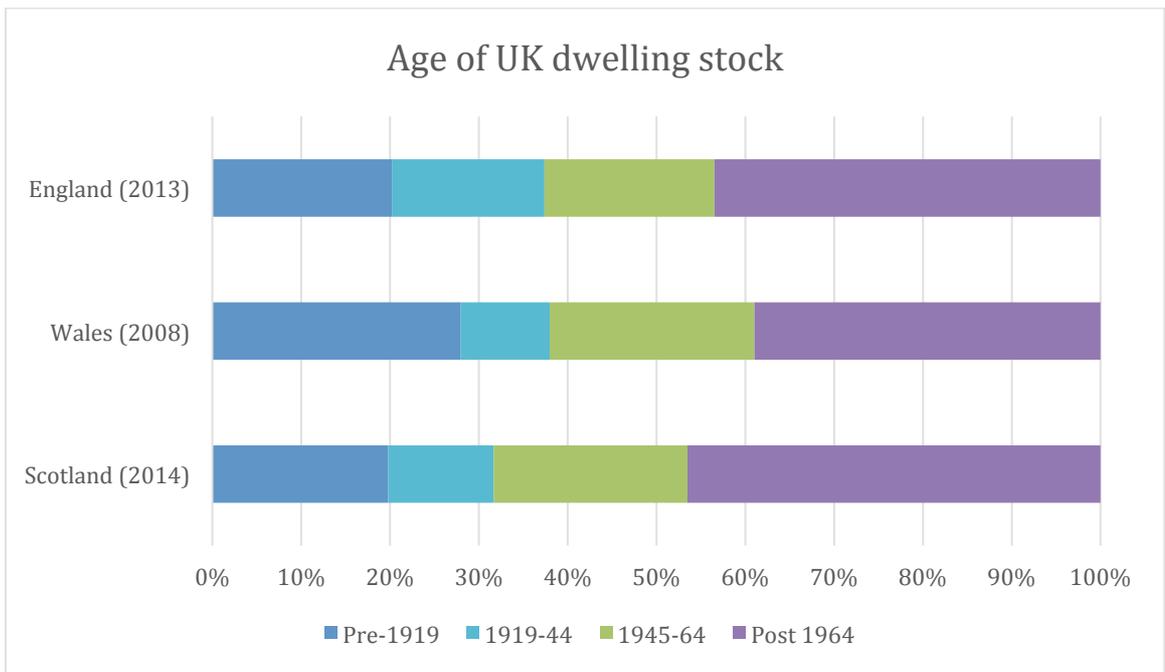


Figure 3 Age of English, Welsh and Scottish dwelling stock (Department for Communities and Local Government, 2015a, DHRW, 2015, The Local Government Data Unit - Wales, 2010)

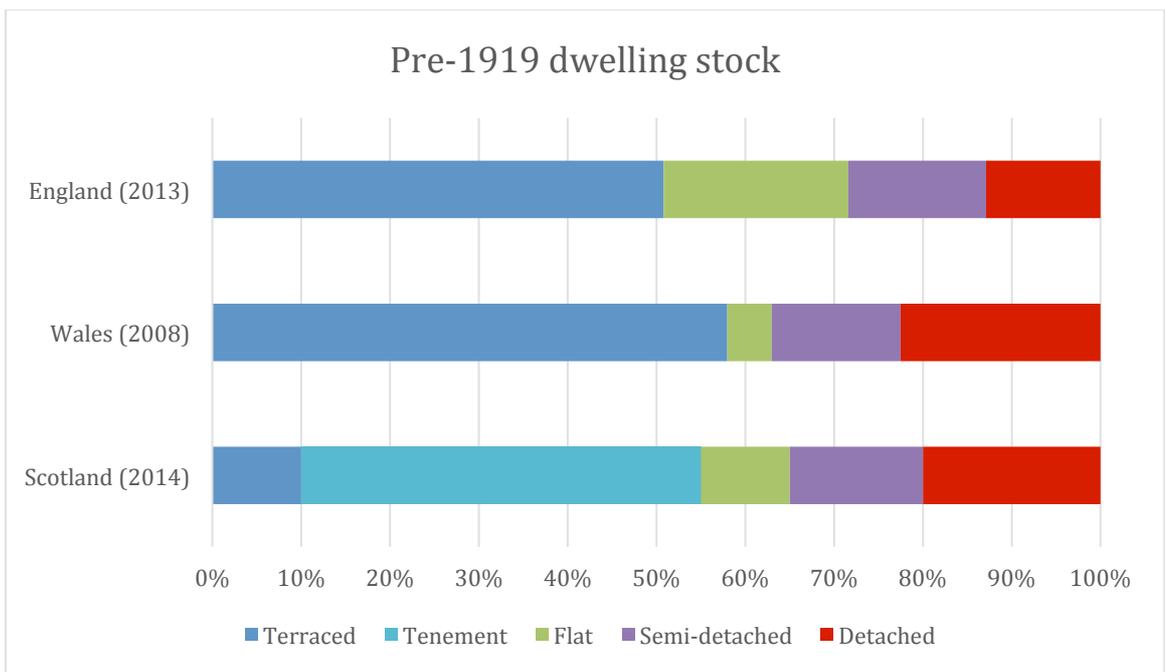


Figure 4 Components by typology of English, Welsh and Scottish dwelling stock built pre-1919 (Department for Communities and Local Government, 2015a, DHRW, 2015, The Local Government Data Unit - Wales., 2010)

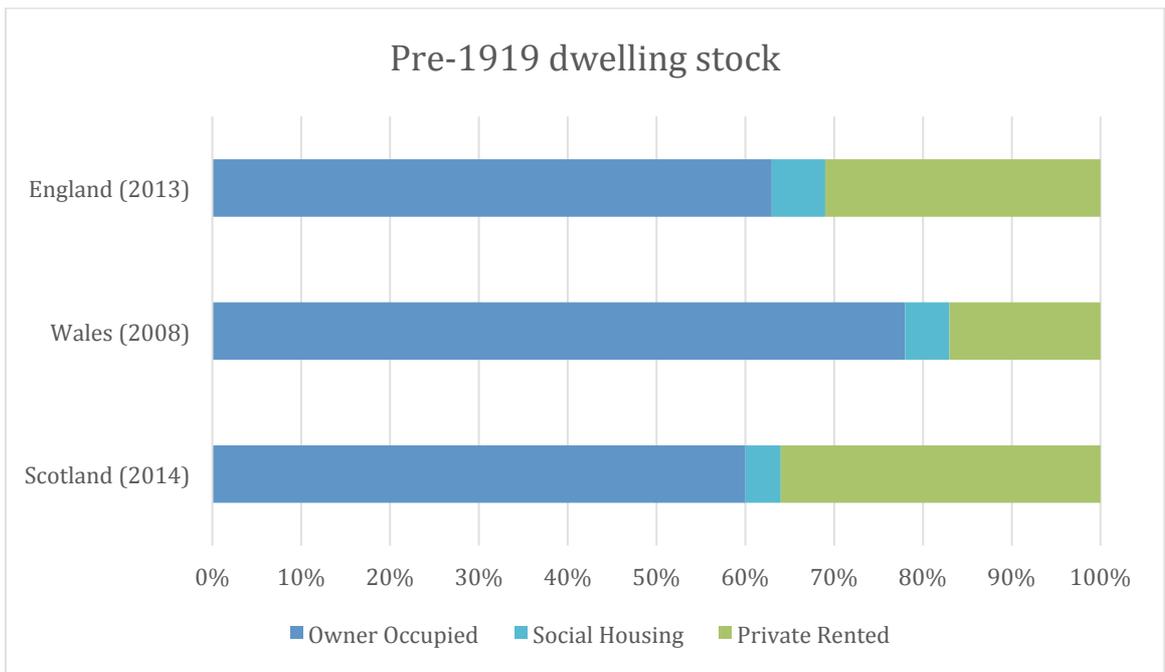


Figure 5 Components by tenure of English, Welsh and Scottish dwelling stock built pre-1919 (Department for Communities and Local Government, 2015a, DHRW, 2015, The Local Government Data Unit - Wales, 2010)

The English housing stock data

The English Housing Survey is a continuous national survey first conducted in 2008-09, replacing its predecessors the English House Condition Survey and the Survey of English Housing. The latest report published 2015 is presented as the figures for “2013” but is based on fieldwork carried out between April 2012 and March 2014. The survey comprises a physical inspection of 12,498 occupied or vacant dwellings. This sample represents just over 0.05% of the overall English dwelling stock. The survey shows that in England 20% of the dwelling stock was built pre-1919 (Department for Communities and Local Government, 2015a).

Figure 6 shows the Energy Performance Certificate rating for the dwellings covered by the English Housing Survey. As previously noted these ratings are not a true reflection of the energy use of the buildings, being based on calculations involving assumptions rather than measured data. The distribution is almost too regular, suggesting preconceived energy demand patterns rather than actual energy use. Older buildings are assumed to be less efficient, as are detached properties due to their increased surface to volume ratio. This clearly highlights the need for measured energy data, or simulation based on measured variables and not preconceived assumptions.

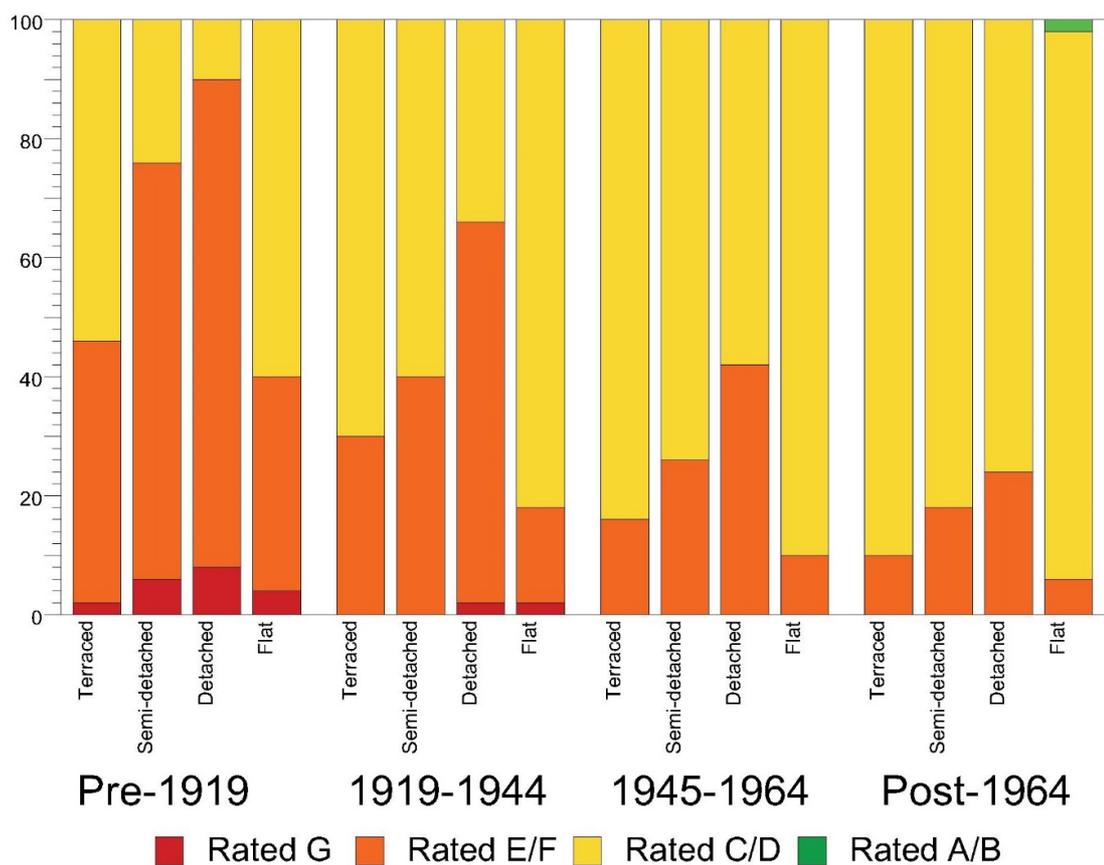


Figure 6 Energy Performance Certificate rating of houses included in English Housing Survey 2013 (Department for Communities and Local Government, 2013)

Welsh housing stock data

A survey of the Welsh housing stock was last undertaken in 2008 as part of the Living in Wales Survey. A full report on the data appears not to have been published, however as previously mentioned, datasets from this survey are available through the UK Data Service. A new Welsh housing condition survey is possibly planned for 2017-18 or 2018-19. The 2008 survey covered 2,741 dwellings representing 0.2% of the housing stock. The survey showed that 28% of the dwelling stock was built pre-1919. It is interesting to note that between 1998 and 2008 the percentage of pre-1919 dwellings dropped from 32% (Welsh Government, 2001) to 28% (The Local Government Data Unit - Wales, 2010). This decrease is most probably due to the combination of both the construction of new dwellings and the demolition of pre-1919 housing stock.

According to a survey of the private building stock in Bridgend County 29.3% of the private housing stock was built pre-1919 and the most common type is pre-1919 terraced housing (Fordham Research, 2009). The survey estimated that the average cost per dwelling for urgent repairs was £1,226, rising to £2,144 for basic repairs (necessary in next 5 years) and £3,837 for comprehensive repairs (Fordham Research, 2009). 13.4% of all private sector households were deemed to be fuel poor (need to spend more than 10% of income on fuel use) with 30.7% of private rented households suffering from fuel poverty.

Scottish housing stock data

The latest report on the Scottish Housing condition survey was published in 2015 (DHRW, 2015). Based on 3,787 interviews and 2,682 physical surveys (0.11% of the total dwelling stock) conducted in 2014. The survey showed that 20% of Scotland's

occupied dwellings were built pre-1919, of which 10% are terraced, 15% are semi-detached, 45% are tenements, 10% are other flats and 20% are detached.

The report states that overall the pre-1919 dwellings are on average 25% larger (DHRW, 2015), however the average floor area of an urban pre-1919 dwelling is only 7% larger than an urban dwelling built post 1982, with the greater reduction in size predominantly being seen in the rural housing stock.

72% of uninsulated solid masonry walls in Scotland were built pre-1919 (DHRW, 2015). Using the 2009 SAP methodology 17% of Scottish pre-1919 dwellings are rated C or better, 71% between D&E and 12% rated F&G, this age of dwelling accounts for the largest proportion of low rated dwellings (DHRW, 2015). When the 2012 SAP methodology is applied, the percentage of pre-1919 dwellings rated F&G rises to 19%. 43% of households living in pre-1919 dwellings were reported to be suffering from fuel poverty in 2014 (DHRW, 2015), this compares to only 21% of households living in post-1982 dwellings.

Draughts were the most cited reason for private renters to find it difficult to heat their house, with more citing this reason than their house owner and social sector counterparts (DHRW, 2015). More social sector tenants than private tenants cited not being able to heat the house due to economic reasons.

With regards to the condition of dwellings in Scotland the need for urgent or critical repair diminished with age, with the pre-1919 stock having the highest percentage requiring attention at 72% (DHRW, 2015). With regard to tenure it was the private rented sector that presented the highest percentage of dwellings in disrepair. 12.6% of Scottish households had problems with damp, of which 74% was condensation, 22% penetrating damp and 4% rising damp.

Element	Percentage of households (%)	Extent per dwelling (%)
External Wall Finishes	31	2
Chimney Stacks	27	2
Roof Coverings	19	2
Flashings	16	2
Gutters and Downpipes	15	2
Windows	9	2
External doors	6	1
Wall Structure	3	2
Roof Structure	<1	
DPC	<1	
Foundations	<1	

Table 2 Percentage of Scottish households affected and average extent of disrepair to external critical elements (after DHRW, 2015)

6. Data on condition of English, Welsh and Scottish housing stock

Climate

Before comparing the condition of the domestic building stock of the three nations it is important to put this information into context with regard to the climates that each faces. The following three graphs (Figures 7-9) show the mean temperatures, rainfall, sunhours and days with air-frost. These clearly show that Wales and Scotland have higher levels of precipitation and that temperature and sunhours decrease England-Wales-Scotland, whilst days with frost increase inversely.

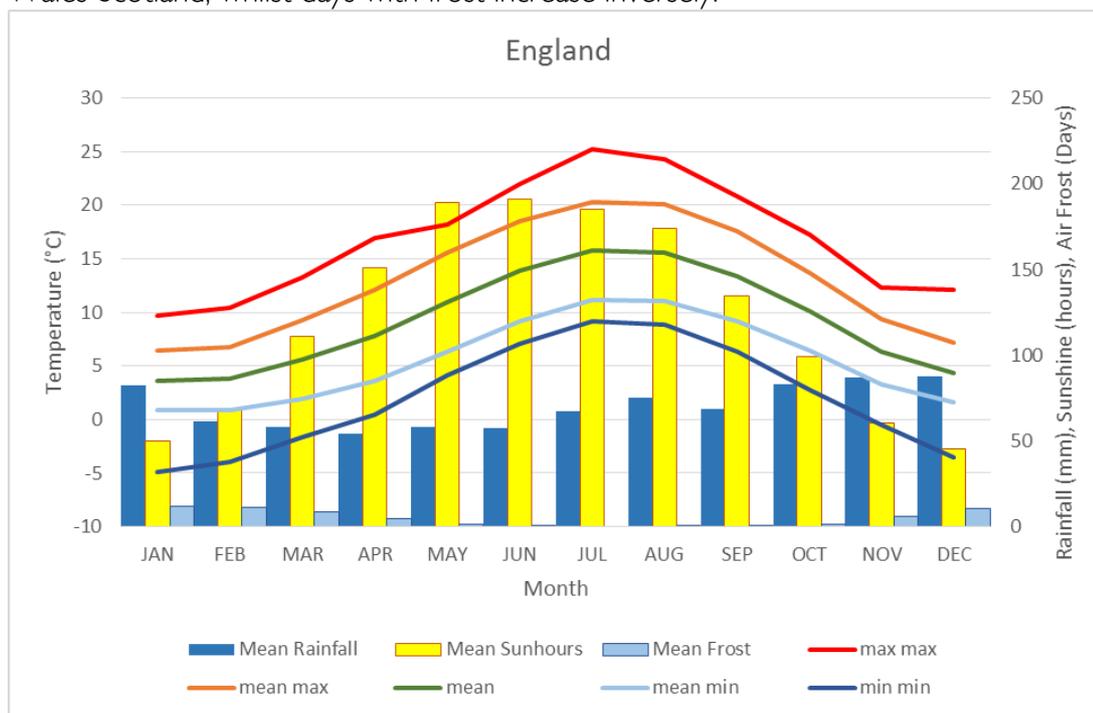


Figure 7 Climatic data for England based on data from 1910-2015 (Met Office, 2016)

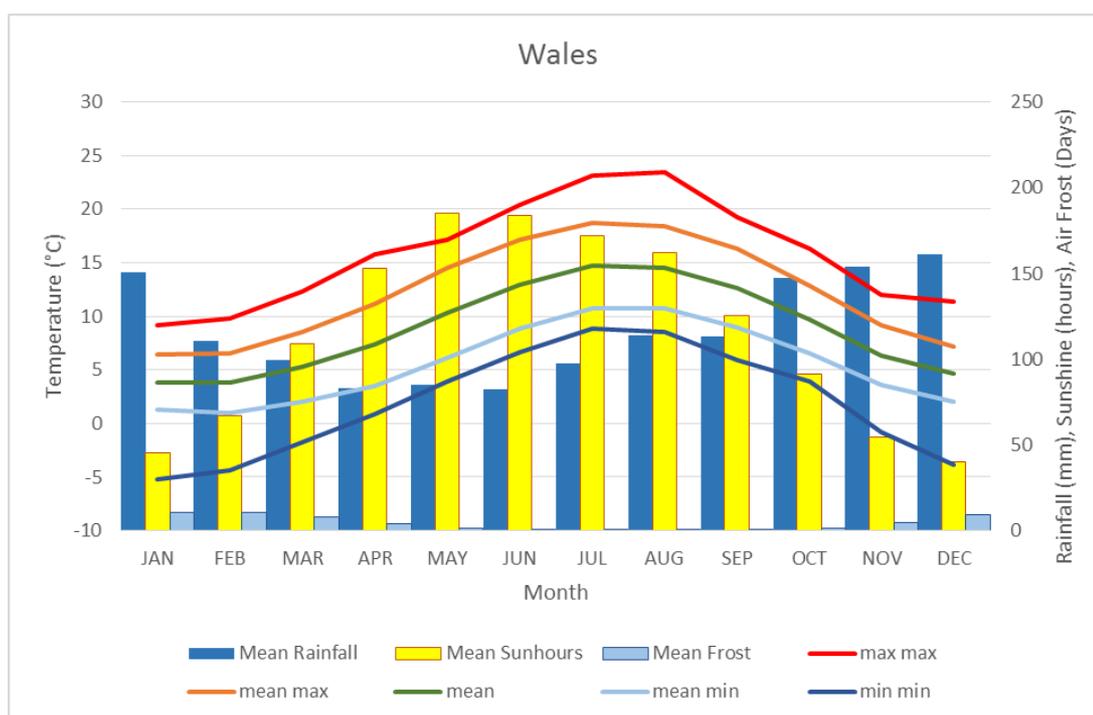


Figure 8 Climatic data for Wales based on data from 1910-2015 (Met Office, 2016)

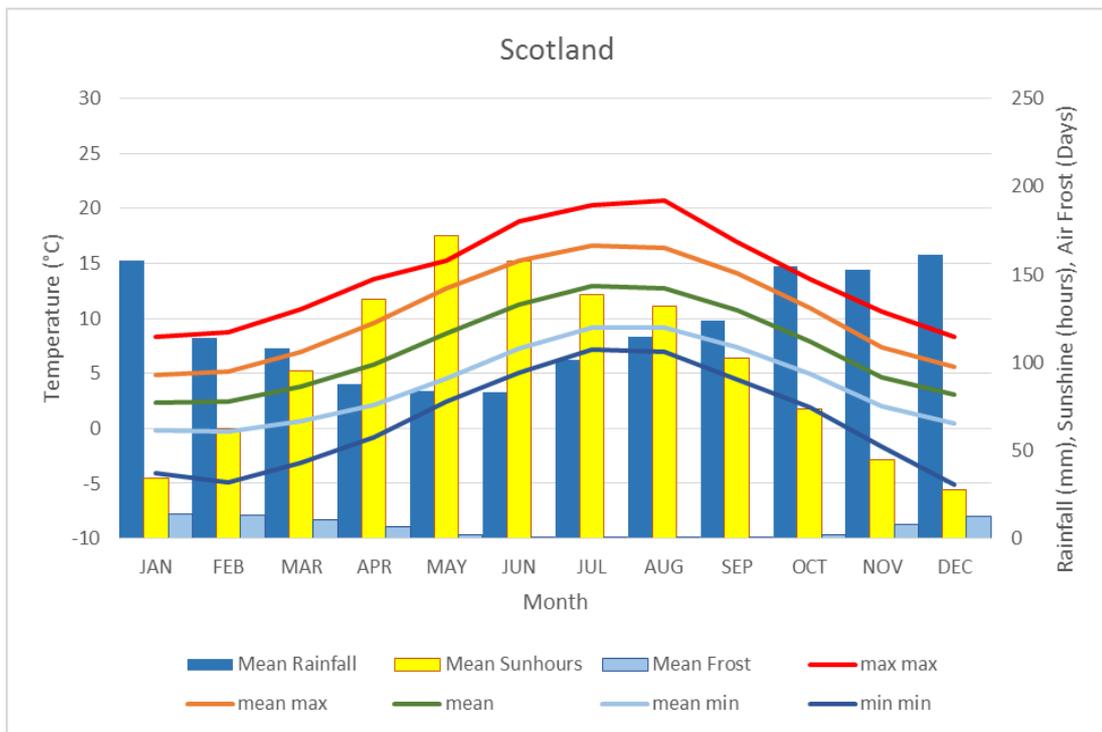


Figure 9 Climatic data for Scotland based on data from 1910-2015 (Met Office, 2016)

Properties affected by damp

The following graphs (Figures 10-12) show the number of dwellings recorded by the English (Department for Communities and Local Government, 2013), Welsh (The Local Government Data Unit - Wales, 2010) and Scottish (Scottish Housing Condition Survey Project Team, 2014) Housing Condition Surveys affected by either penetrating or rising damp. Given that each survey covered a different number of dwellings a direct numerical comparison is not possible. It is however possible to compare the overall distribution of those properties affected by damp according to age, typology and tenure. In England, Figure 10 clearly shows that pre-1919 terraced houses are the most affected by penetrating or rising damp. Of these properties 60% are in the social sector, 37% are owner-occupied and 3% are rented from private landlords. Pre-1919 flats are the second biggest group suffering from damp and are again dominated by the social sector which makes up 84% of this group, with owner-occupied and private rented flats accounting for only 8% each.

In Wales (Figure 11) again, pre-1919 terraced houses are the property most affected by damp, however in this case it is owner-occupied properties that account for the largest percentage at 70%, followed by private rented at 26%, with the social sector only accounting for 4% of the pre-1919 terraced houses suffering from damp. The second group most prevalent to damp are pre-1919 detached houses where again the majority are owner-occupied (83%).

In Scotland where terraced housing is not such a dominant typology it is pre-1919 detached houses that form the group most affected by penetrating or rising damp. Of these 80% are owner-occupied and 20% rented from private landlords. Tenements, Scotland's most common pre-1919 housing typology, is second with regards to occurrence of damp, followed by flats. Perhaps the most striking difference between Scotland and England and Wales is that damp is more evenly spread across the housing stock. Whilst more cases of damp were recorded in the Scottish pre-1919 dwellings

than those of other periods, there was not the same dramatic distinction seen in the other nations. This could perhaps be attributed to the colder damper Scottish climate.

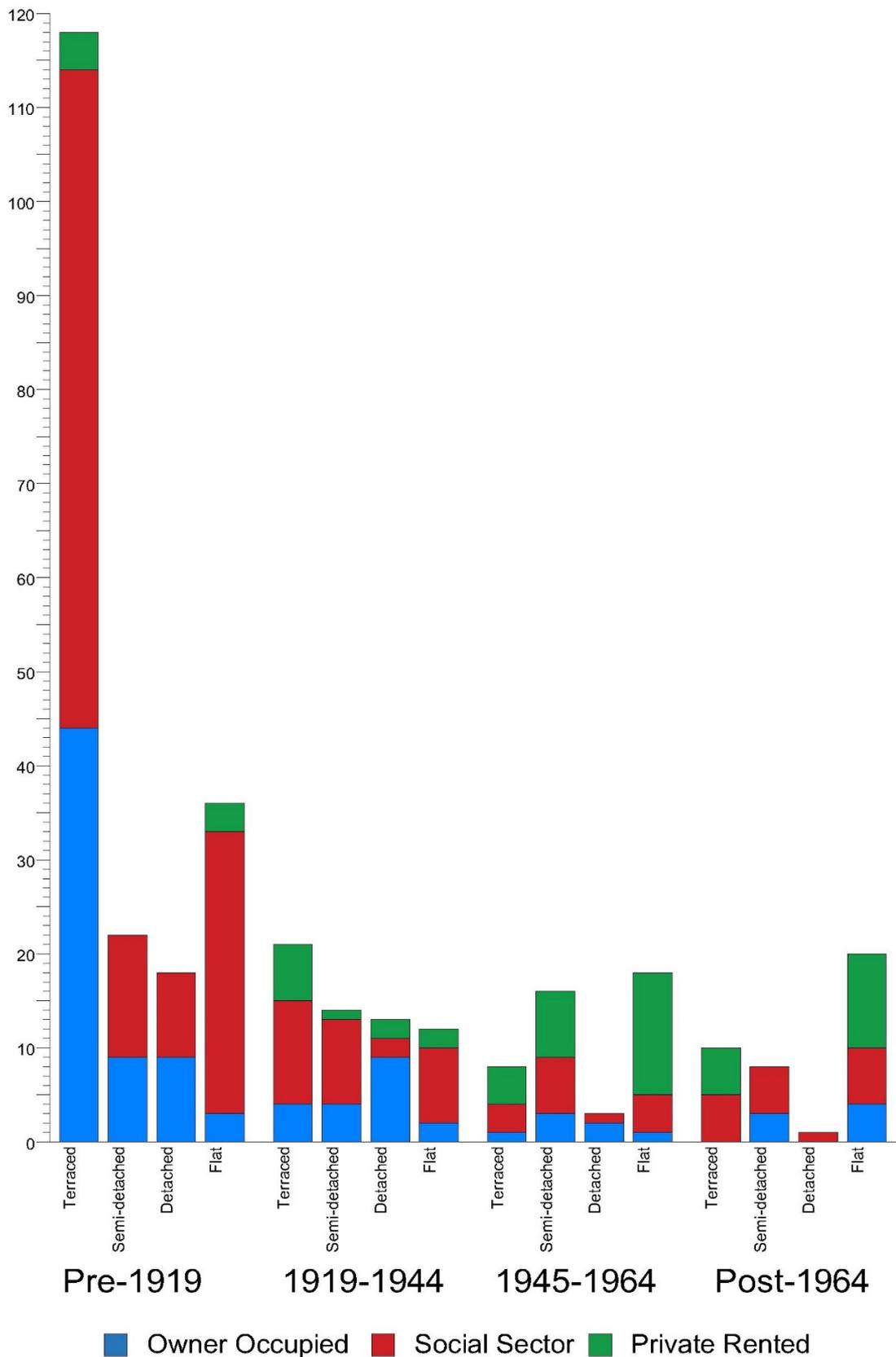
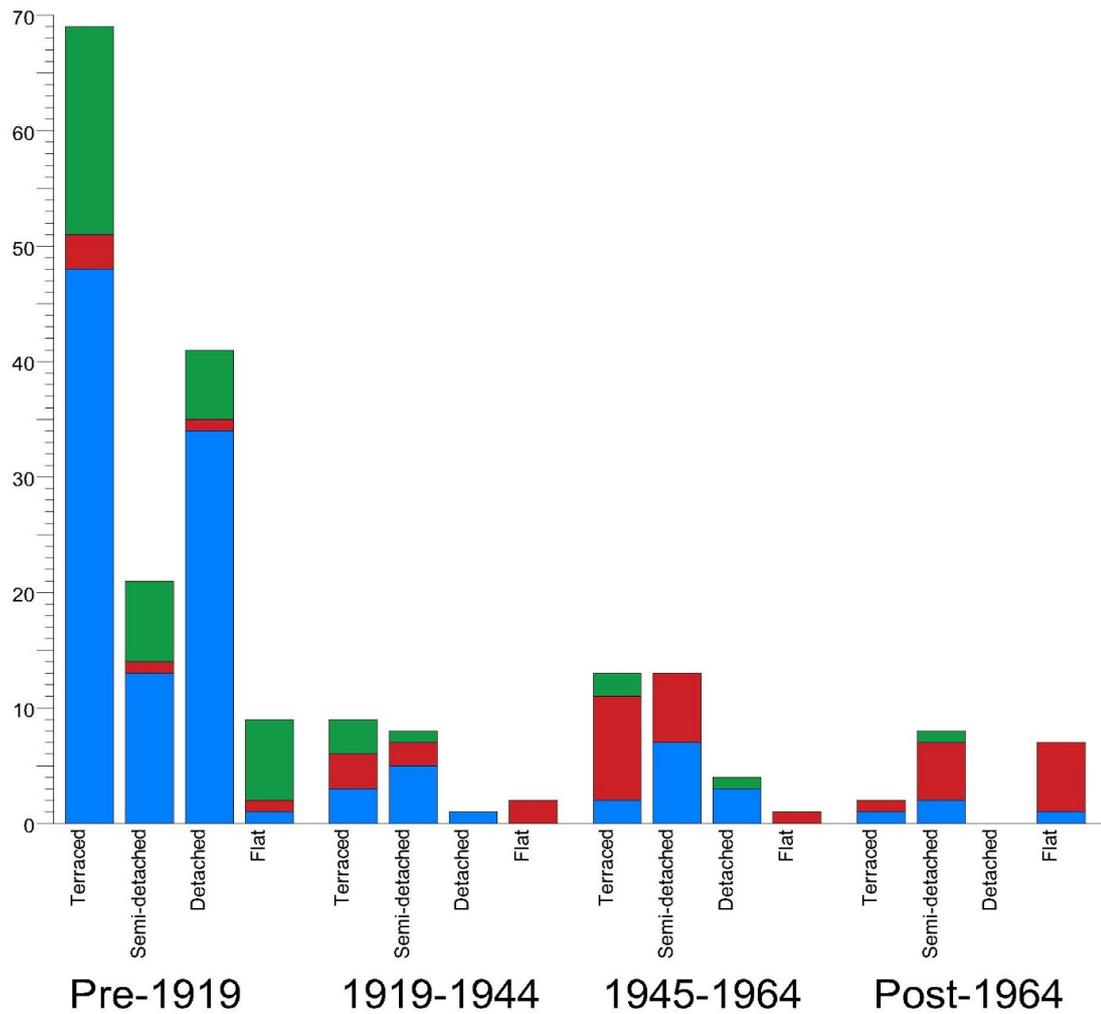
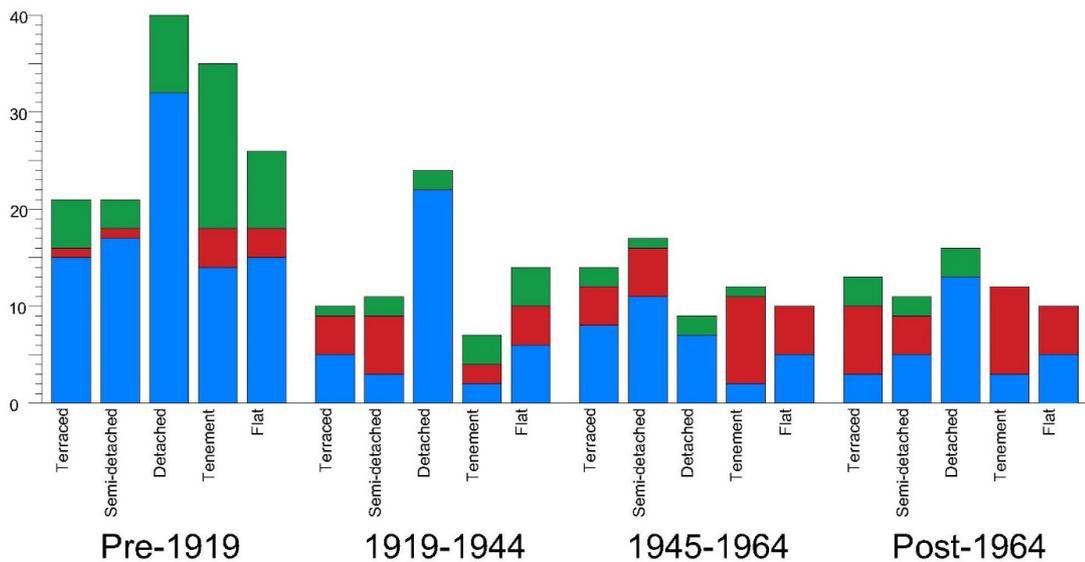


Figure 10 Properties with rising damp and penetrating damp, England (Sample of 12,763 dwellings) (Department for Communities and Local Government, 2013)



■ Owner Occupied ■ Social Sector □ Private Rented

Figure 11 Properties with rising damp and penetrating damp, Wales (Sample of 2741 dwellings) (The Local Government Data Unit - Wales, 2010)



■ Owner Occupied ■ Social Sector ■ Private Rented

Figure 12 Properties with rising damp and penetrating damp, Scotland (Sample of 11,543 dwellings) (Scottish Housing Condition Survey Project Team, 2014)

Disrepair

Moving on to look at the correlation between the levels of disrepair, building age, typology and tenure, we see a similar pattern of distribution to that seen in the levels of damp. Again using the data from the English (Department for Communities and Local Government, 2013), Welsh (The Local Government Data Unit - Wales, 2010) and Scottish (Scottish Housing Condition Survey Project Team, 2014) Housing Condition Surveys, Figures 13-15 show those properties surveyed that showed signs of disrepair. Each survey measures disrepair using different criteria and as before each survey covers a differing number of dwellings. It is therefore only possible to assess general trends and distribution and not make direct numerical comparisons.

In the case of England (Figure 13) the Decent Homes standard has a specific criterion looking at disrepair. Those properties shown in graph are those which failed this component of the standard. The distribution of those properties failing the disrepair component is similar to the distribution of properties affected by damp. Pre-1919 terraced houses are by far the biggest single group. However the percentage of owner-occupied properties in this category increases, representing 46% of these properties, 51% are social sector and 3% privately rented. Pre-1919 flats are again the second largest group, however other newer properties such as 1945-1964 semi-detached houses, 1919-1944 semi-detached houses and 1919-1944 terraces also show high levels of disrepair.

A similar spread of disrepair can be seen in those properties surveyed in the Welsh survey (Figure 14). Again, as with damp, the largest single group with evidence of disrepair is pre-1919 owner-occupied terraced houses at 72%. The social sector appears to have more cases of disrepair in the newer properties probably due to the fact that there are few pre-1919 social sector dwellings in Wales.

The story is however quite different in Scotland (Figure 15) where the largest group with disrepair to critical elements is post-1964 dwellings, the majority of which (93%) are owner-occupied. The pre-1919 typology with most disrepair is tenements, of which 42% are owner-occupied, 42% private rented and 16% from the social sector.

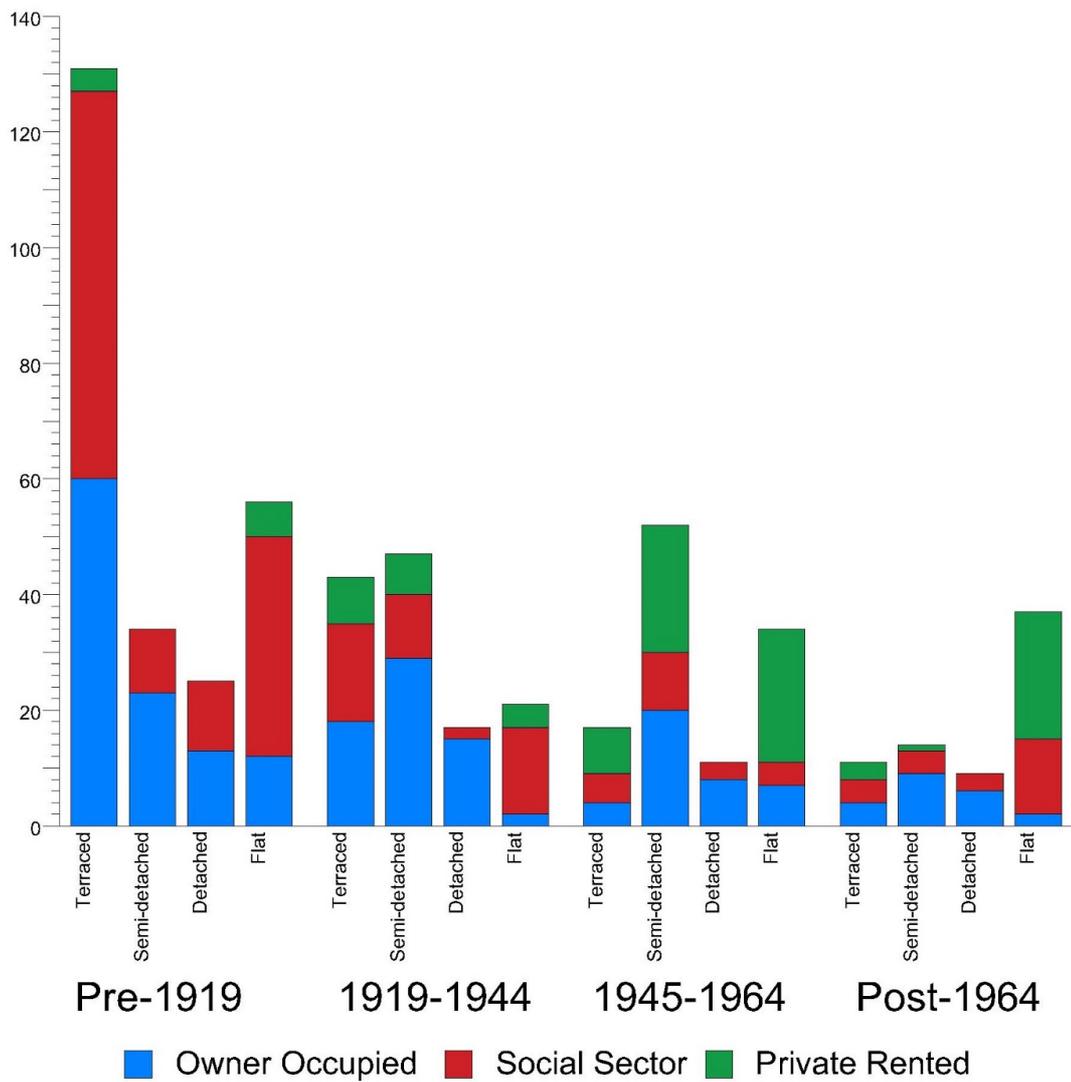


Figure 13 Properties failing the “Decent Homes” Disrepair component, England (Sample of 12,763 dwellings) (Department for Communities and Local Government, 2013)

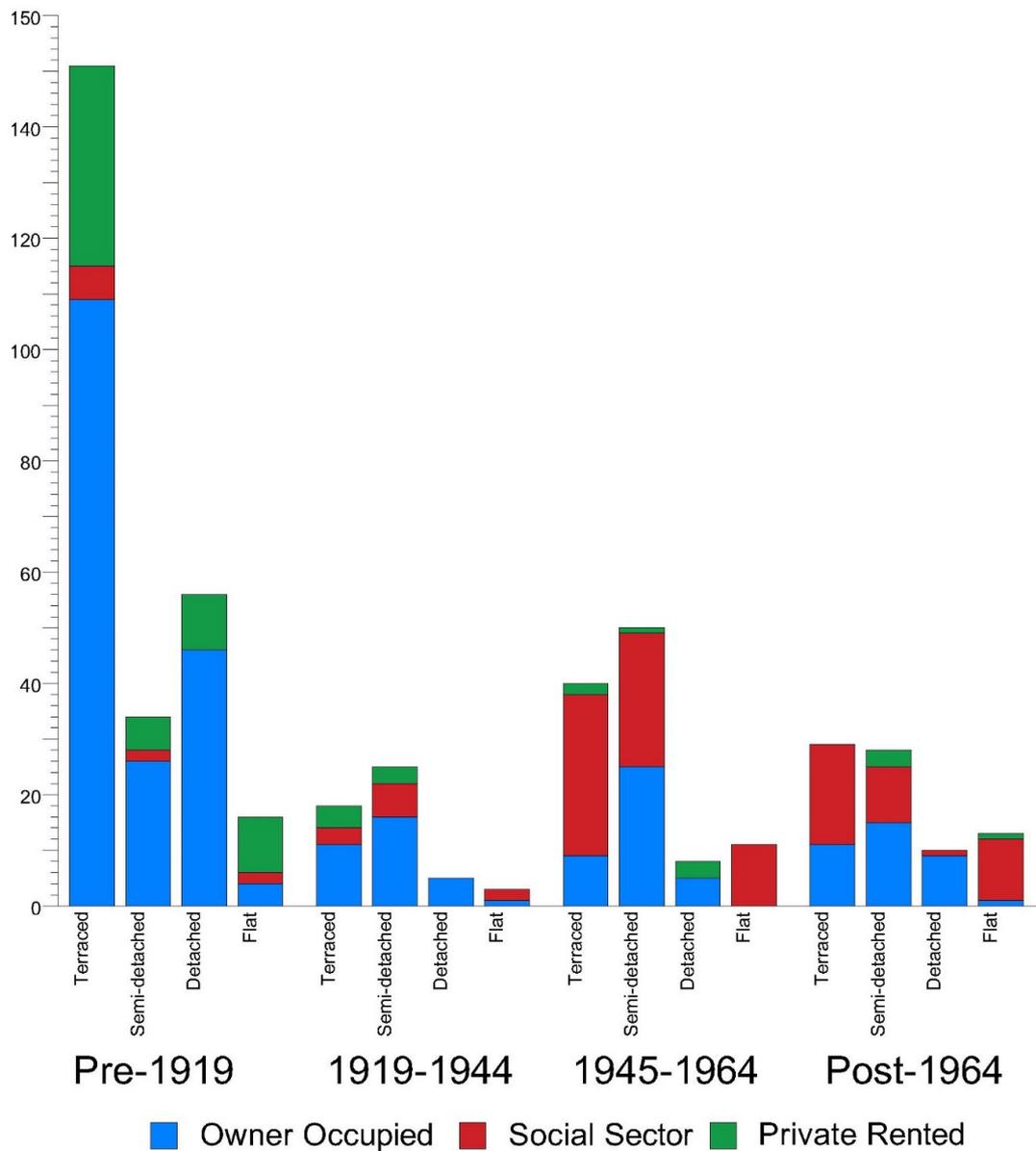


Figure 14 Properties with evidence of disrepair, Wales (Sample of 2741 dwellings) (The Local Government Data Unit - Wales, 2010)

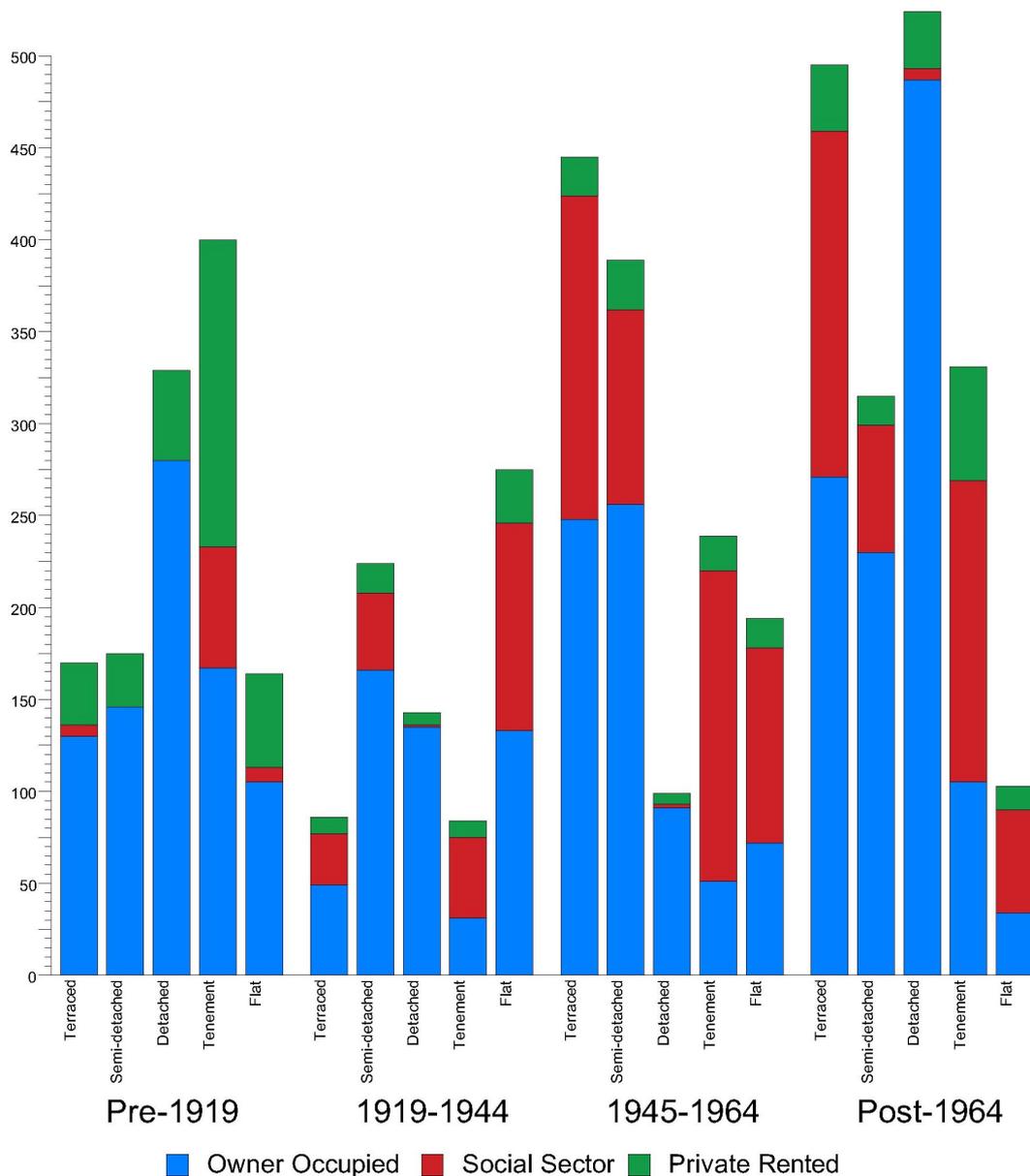


Figure 15 Properties with disrepair to critical elements, Scotland (Sample of 11,543 dwellings) (Scottish Housing Condition Survey Project Team, 2014)

Overall these graphs show that in England and Wales it is pre-1919 terraced houses that lack the most maintenance with problems both of damp and disrepair. How this lack of maintenance then goes on to impact on the energy use and comfort of these dwellings is however difficult to quantify. As previously mentioned the data on energy use collected by the survey is based on SAP calculations and not real measured energy use, nor calibrated dynamic modelling.

7. Non-domestic building stock

Valuation Office Agency, Inland Revenue

The Valuation Office Agency (VOA) is an executive agency, sponsored by Her Majesty's Revenue and Customs. The VOA provides the government with data on the rateable properties in England and Wales. Their remit covers both domestic properties

via the Council Tax and non-domestic properties. The data they hold is based on “hereditaments” which are pieces of floor or land with a single occupant or landlord. General summaries of the number of hereditaments are published by region, property description (use) and rateable value. More detailed information must be requested from the VOA. Professor Philip Steadman, one of the authors of the Non-Domestic Building Energy Fact File (Pout et al., 1998), currently working on a 3D model of the non-domestic building stock (see below (Evans et al.)), stated in a personal email “The VOA do actually hold data on building age, as well as some information about condition where this affects the value of buildings: but at present they don’t make those data fields available [for individual buildings]. We’ve pressed them hard, and will press again. Perhaps you would like to join in the pressing?” (Steadman, 2016). If made public this detailed data could be very valuable for any future project on the condition of the non-domestic building stock in England and Wales. However, aggregated data for England and Wales was requested and received. This shows (Figure 16) that 33% of all offices in England and Wales were built pre-1919, as were 48% of all retail buildings.

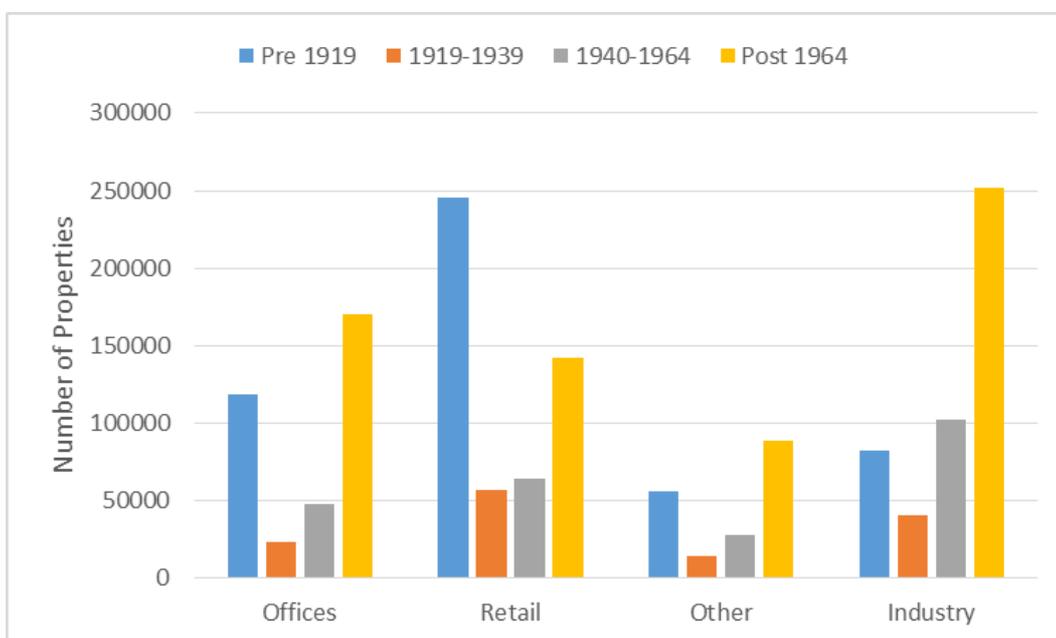


Figure 16 Non-domestic building stock of England and Wales classified by class and age, measured by individual property. Based on (VOA, 2016)

This data is further broken down by regions in England, although not for Wales. This is presented in Figure 17, which shows that the non-domestic building stock is unevenly distributed across the country, and that the age profile varies from region to region. In the North West and London the pre-1919 building stock outweigh their post-1964 counterparts, whereas in Wales they are equal and in in Yorkshire and Humberside there remain very few pre-1919 non-domestic buildings. This aggregated data begins to show the possibilities for further research should the VOA release more detailed information on individual buildings.

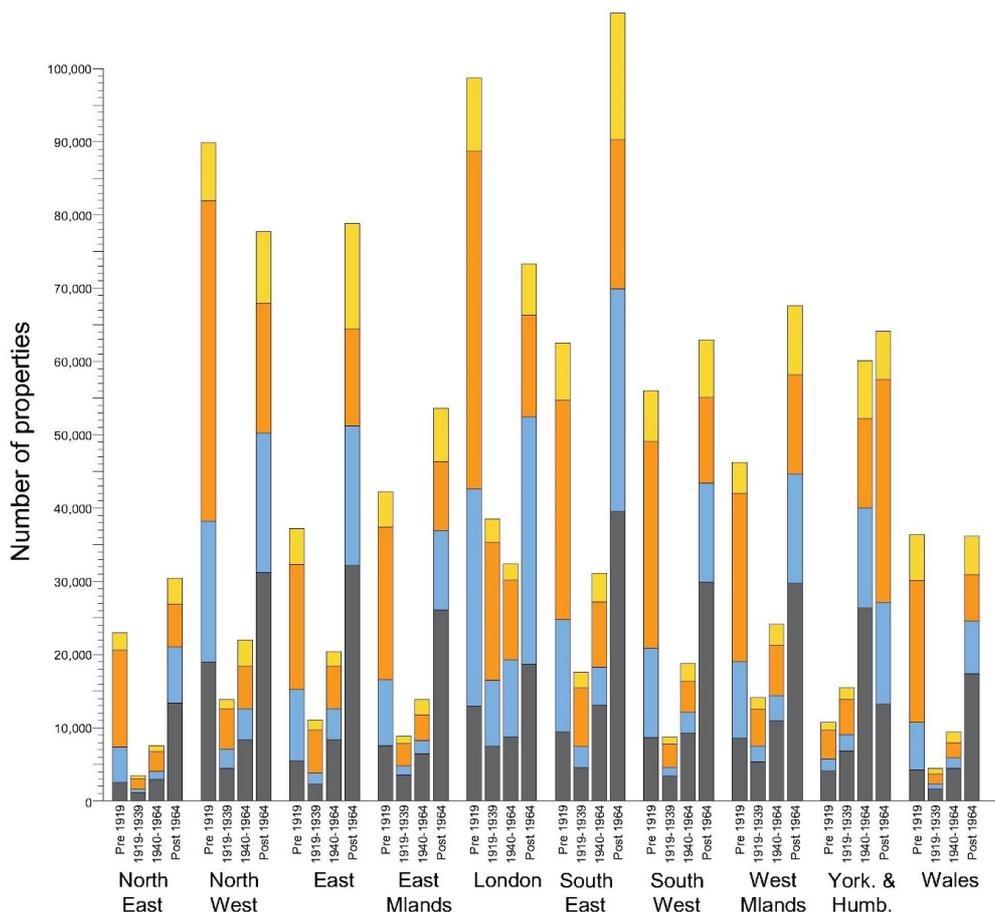


Figure 17 Non-domestic building stock of England and Wales classified by location, class and age, measured by individual property. Based on (VOA, 2016)

Scottish Assessors Association

The Scottish Assessors Association (SAA) performs a similar role to the VOA in Scotland.

The Geoinformation Group

The Geoinformation Group <http://www.geoinformationgroup.co.uk/> is a private company providing geographic information across the UK. Their “UK Building” database holds information on 14.3 million properties. The company claims that it is possible to search for properties based on use and age, and extract floor area measurements. There have however been some concerns raised over the accuracy of their dating of the building stock (Hudson, 2016, Steadman, 2016).

BRE Non-domestic Building Energy Fact File

This BRE publication was published in 1998 and was funded by Global Atmosphere Division of the Department of the Environment, Transport and the Regions. The information presented was based on information from the Valuation Office Agency (VOA, 2016) and research undertaken by the Resources Research Unit at Sheffield Hallam University and the Centre for Configurational Studies at the Open University (Pout et al., 1998). Although now 18 years out of date it still gives an overview of the non-domestic building stock in the UK and more specifically England and Wales. Figure 18 shows the non-domestic building stock of England and Wales classified by class and age, measured by individual property, whereas Figure 19 shows the non-domestic building stock of England and Wales classified by class and age, measured by floor area. This shows that in 1998 49% of all offices buildings were built pre-1919, as were 58% of

all retail buildings. However, due to the increased size of modern office and retail buildings, only 29% of office floor space and 41% of retail floor space dates from this period. Even so there is still more retail floor area built pre-1919 than 1964-1998. Overall, in 1998, 45% of non-domestic buildings were pre-1919 and 25% of the non-domestic floor area. Given the construction of new buildings and demolition of old over the past 18 years, these figures are unlikely to still be an accurate representation of the current non-domestic building stock. It is interesting to compare these figures with the latest data received from the VOA. This shows that there has been a dramatic decrease in the number of pre-1919 retail buildings, with an apparent reduction of around approximately 100,000 properties. Whether this reduction is due to demolition, change of use or revisions to estimates of the buildings age requires further research. Should it turn out to be due to demolition this is an area of great concern.

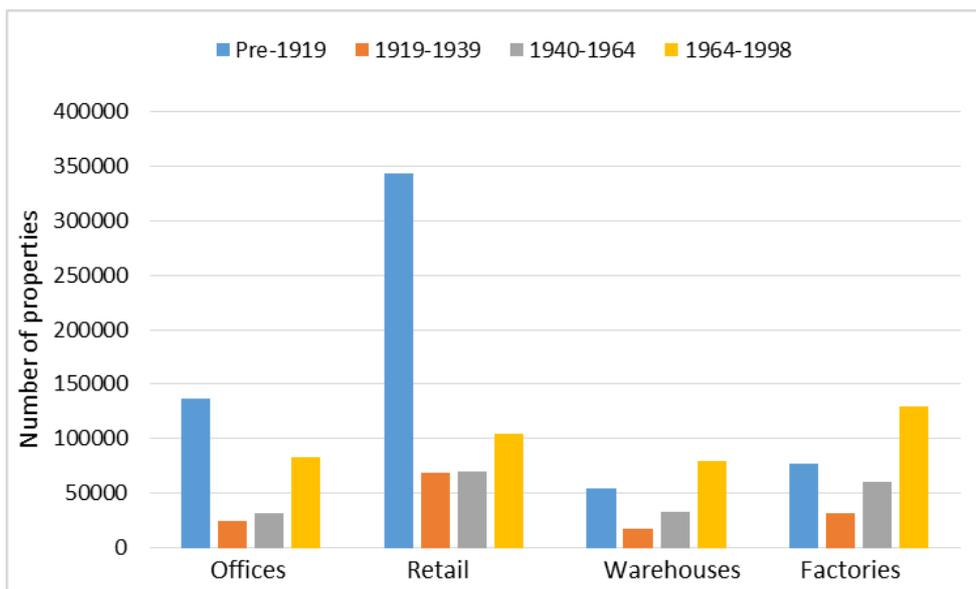


Figure 18 Non-domestic building stock of England and Wales classified by class and age, measured by individual property. Based on (Pout et al., 1998)

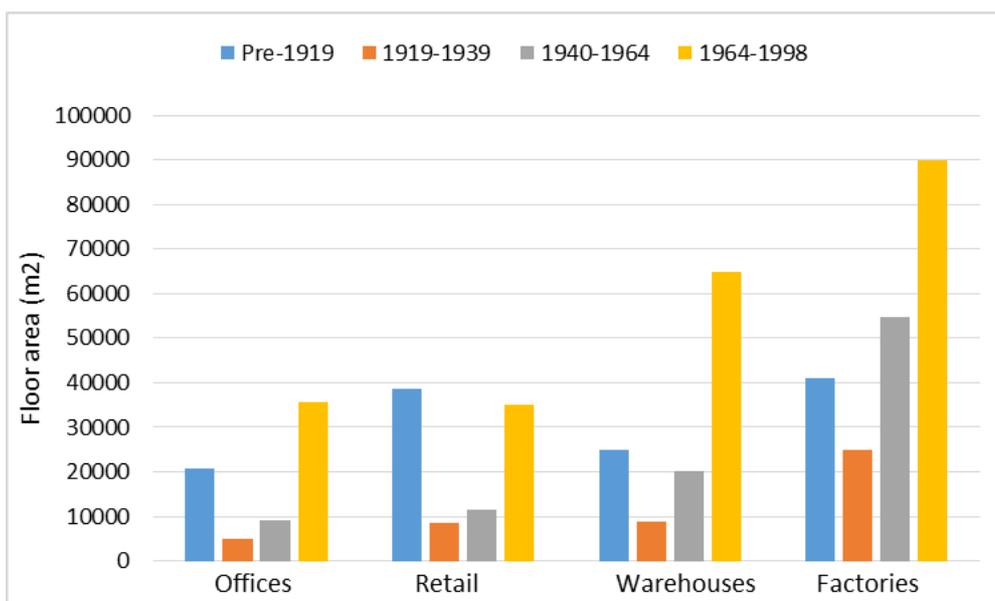


Figure 19 Non-domestic building stock of England and Wales classified by class and age, measured by floor area. Based on (Pout et al., 1998)

Non-domestic Building Stock Database Project

The “Non-domestic Building Energy Fact File” contains some of the research that formed part of a wider “Non-domestic Building Stock Database Project”, a project funded by the then Department of Environment, Food and Rural Affairs. One piece of research within this project studied in closer detail the floor space (m²) of commercial properties in selected areas of Manchester, Swindon, Tamworth and Bury St Edmunds. This showed that 43% of the floor space was constructed pre-1919 (Figure 20) (Brown et al., 2000). This is considerably greater than the 25% quoted by the Non-domestic Building Energy Fact File (Pout et al., 1998). This difference may in part be due to the varying building stock age profile as illustrated in Figure 20, it may however also suggest some degree of inaccuracy in the dating of the buildings.

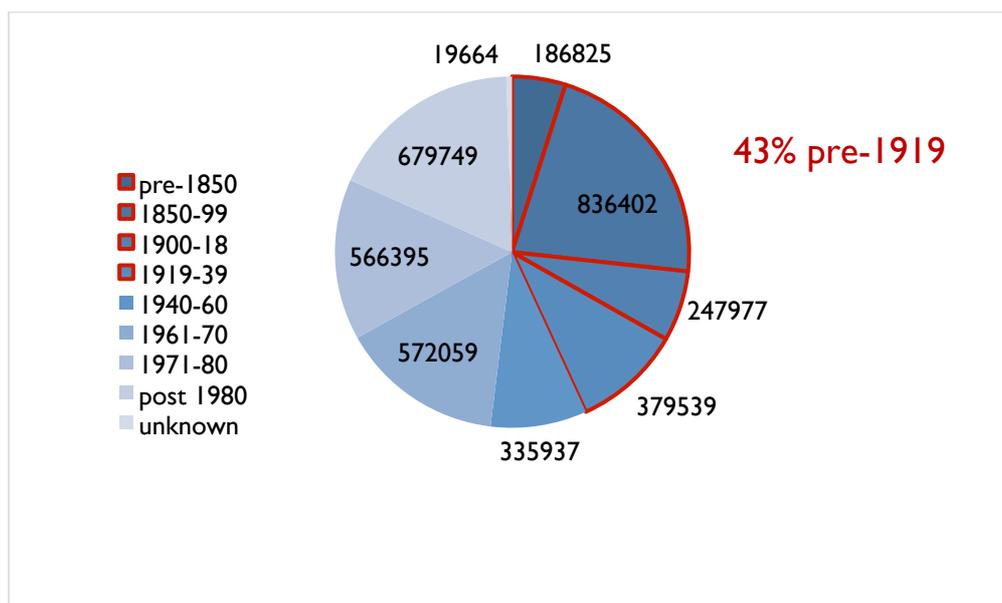


Figure 20 Breakdown of floor space (m²) of commercial property in selected areas of Manchester, Swindon, Tamworth and Bury St Edmunds (Brown et al., 2000)

8. Buildings at risk registers

One way to begin to understand the condition of the historic building stock is via the building at risk registers maintained by Historic England and Historic Environment Scotland. In the case of Wales, it is the local planning authorities that maintain the building at risk register, however, in 2012 Cadw commissioned The Handley Partnership, to undertake an all-Wales condition review of listed buildings over a five-year rolling period, surveying approximately 20% of listed buildings stock in Wales per year. The programme of surveys aims to assess the condition of all 30,000 listed buildings in Wales using consistent methodology.

Buildings at risk in England

The 2015 Heritage at Risk Register published by Historic England contained 5,534 Grade I and II* properties (Historic England, 2015b). Of these, 903 are places of worship. Between 2014 and 2015 604 properties were removed from the register by being repaired, however, 327 new entries were added. Historic England reports that the cost of repairing buildings that have become at risk is increasing, with an average £501,000 required for repair above and beyond the buildings final end value (Historic England, 2015b). It is therefore essential that regular maintenance is undertaken to prevent buildings becoming at risk.

Buildings at risk in Wales

The latest published report from 2013 showed that 8.92% of Welsh listed buildings are at risk, a further 13.81% are vulnerable, whilst 75.1% are stable or in an improving condition (The Handley Partnership, 2013). The report also notes that 66.72% of the listed buildings are fully occupied.

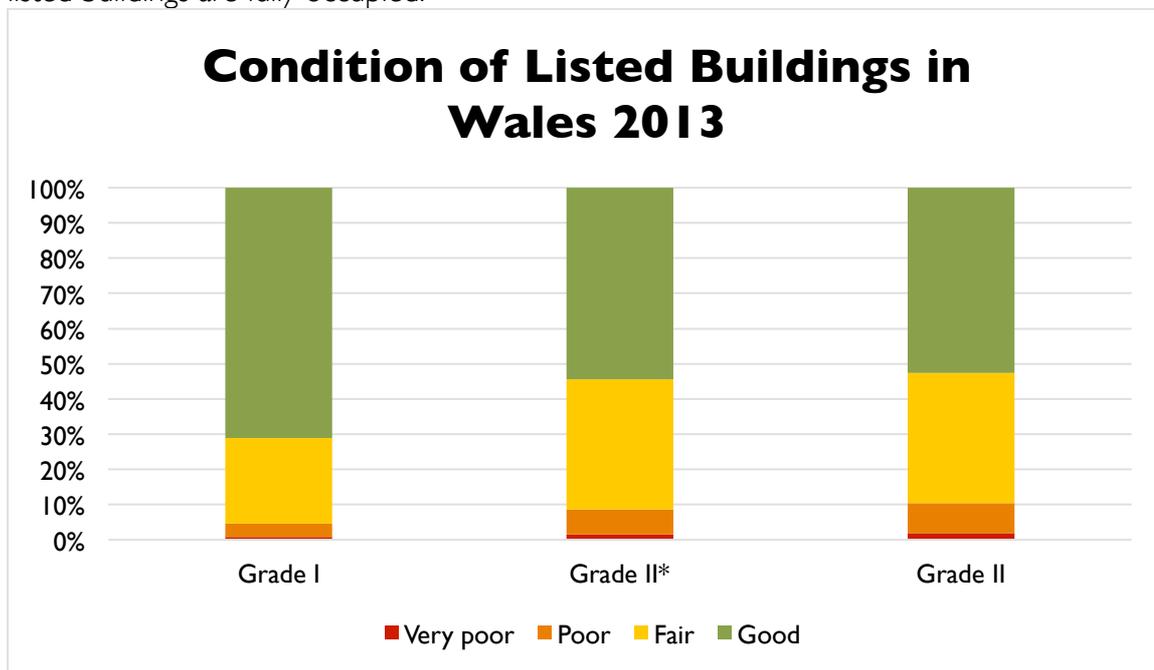


Figure 21 Condition of listed buildings in Wales, as reported 2013 (The Handley Partnership, 2013)

Figure 21 shows the condition of listed buildings in Wales. This shows an increase in disrepair as the listing grade decreases, with Grade I buildings being in the best condition. Could it perhaps be assumed that this trend would continue if non-listed pre-1919 buildings were included?

It was also reported that in terms of number of properties, there are more agricultural and domestic properties at risk than any other type. However, it is extractive and process buildings that have the highest percentage of their listed buildings at risk. Properties in rural locations are more likely to be at risk than their urban counterparts and the Swansea Bay area has the highest concentration of at risk and vulnerable listed buildings (The Handley Partnership, 2013).

Buildings at risk in Scotland

According to Historic Environment Scotland on the 21st March 2016 there were 2547 listed buildings at risk in Scotland (Historic Environment Scotland, 2016a). A total of 2133 buildings have been removed from the list since its inception in 1990, of these 77% have been saved, however the remaining 23% ended up being demolished. Historic Environment Scotland's Building at Risk Register for Scotland website <http://www.buildingsatrisk.org.uk/#> allows lists to be viewed by geographical region. By doing so it is possible to build up a picture of where the buildings at risk are located. Figure 22 shows a map based on this data with a scale from green (10 buildings at risk) to red (271 buildings at risk). This clearly shows that there are fewer buildings at risk in the Central Belt, the two main National Parks, Cairngorm and Loch Lomond and the Trossachs, and Aberdeen. The highest number of buildings at risk can be found in Aberdeenshire with 271 properties, closely followed by Argyll and Bute with 235. It would be interesting in further research to map these statistics against other indicators such as wealth, building type and building age.

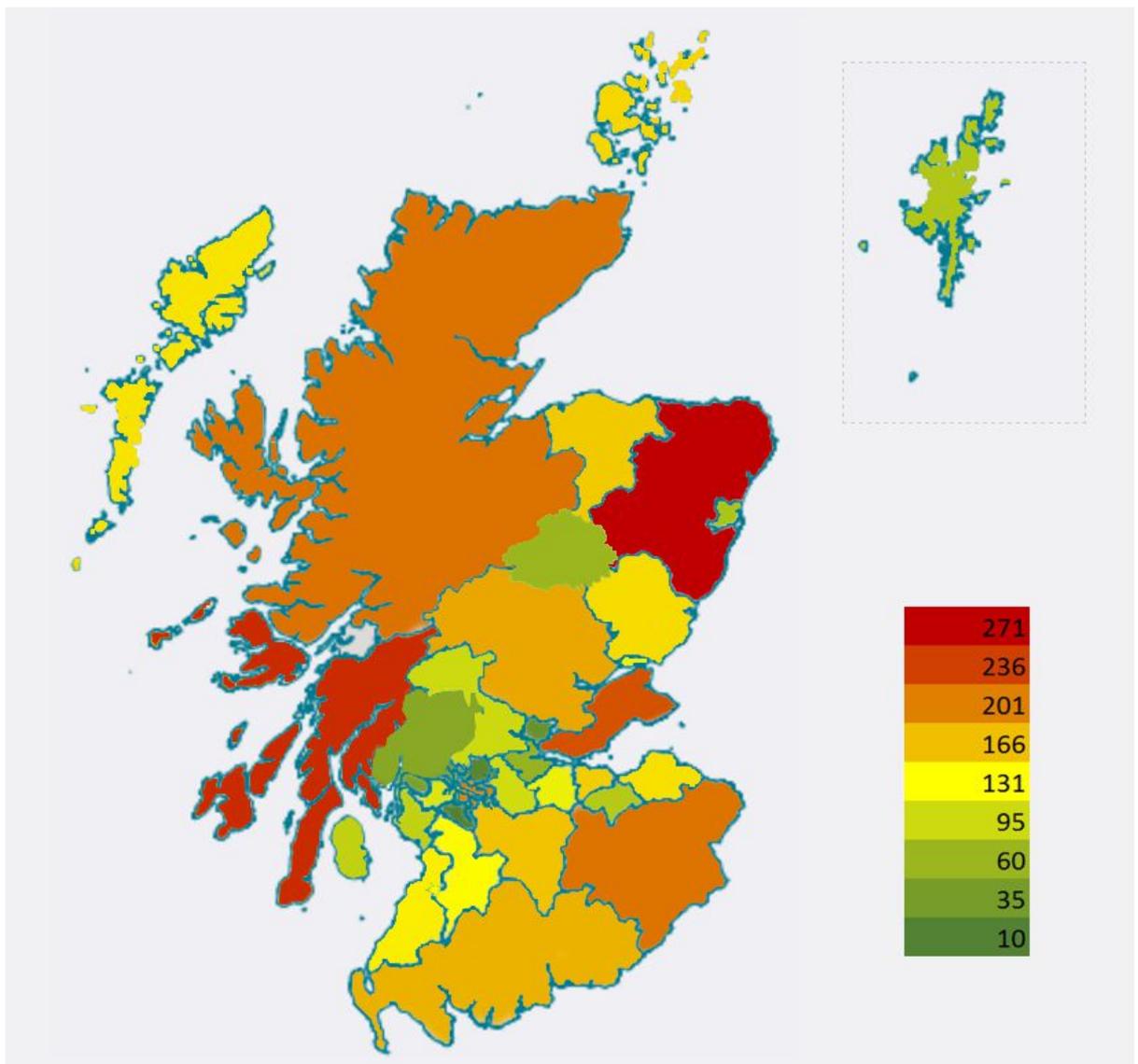


Figure 22 Number of buildings at risk in Scotland by region. C Whitman based on (Historic Environment Scotland, 2016a)

9. Energy data for traditional buildings

Energy Performance Certificates

Energy Performance Certificates (EPCs) were introduced for properties in England and Wales on 1st August 2007, with Scotland introducing them a year and a half later on January 4th 2009. The certificates consist of an Energy Efficiency Rating and an Environmental (CO₂) Impact Rating, both on a scale of A-G and are required for all buildings for sale or rent. However as of January 2013 listed buildings are exempt from requiring EPCs. This therefore limits the worth of any data regarding EPCs, as only of those historic properties sold or let between August 2007 (January 2009 in Scotland) and January 2013. The usefulness of the data arising from EPCs is further diminished due to the limitations of the Simplified Building Energy Model used to calculate the rating and the assumptions that are made as to the efficiency of the building fabric. Were full SAP calculations to be used the accuracy would be increased.

Display energy certificates (DECs)

As of 9th July 2015 all buildings in England and Wales, occupied by a public authority, where the total useful floor area of the building exceeds 250m², and which are frequently visited by the public, must display a Display Energy Certificate (DEC) (Department for Communities and Local Government, 2015b). Although the format of these certificates is almost identical to the previously described EPC, the DEC is based on actual recorded energy use. As such, they provide a far more reliable indicator of the building's energy performance. In addition to being displayed in the building itself, the DEC's are also made publicly available as part of the dataset "Central Government Property and Land including Welsh Ministers estate; Building data" (Cabinet Office, 2015). This dataset also includes the location, floor area, building usage, number of floors, construction date (if known) and listing category (if listed). It therefore provides an invaluable source of information for gaining an overview of the energy performance of historic buildings in England and Wales. Although it should be noted that in the latest published data (Cabinet Office, 2015) only 17% have DEC information provided and only 10% both DEC and known construction date. Figure 23 shows the DEC rating for all buildings by age bracket.

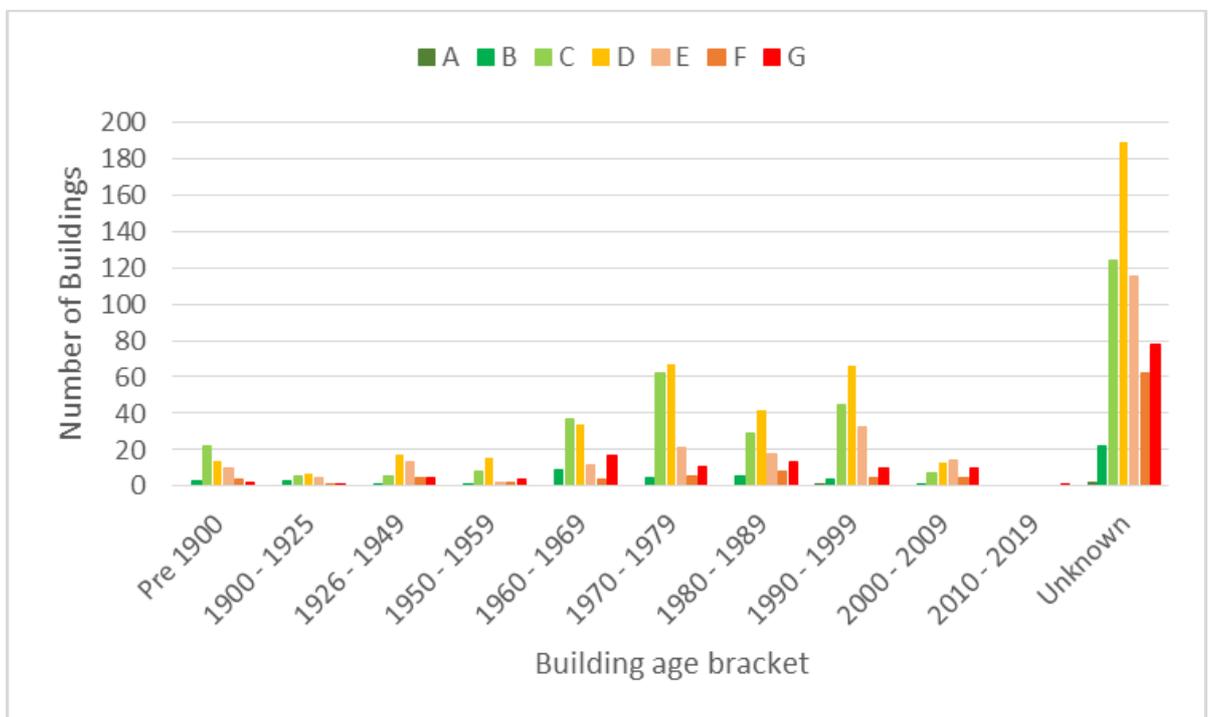


Figure 23 Display Energy Certificate rating for all buildings by age bracket

Whilst the average trend for each age bracket is for D to be the most common DEC, for Pre-1900 buildings C is the most common. Equally, most other age brackets have a higher number of G rated buildings than F rated. In comparison, pre-1900 buildings show a stepped decline from C with only 2 buildings rated G. Using this dataset, further work could be undertaken looking at the correlation between energy performance, building age, building location, designation listing, floor area and number of floors.

Sector specific studies

There follows a summary of two pieces of research that look at specific sectors within the built stock, namely law courts and museums. The results from both challenge the common assumption that older buildings are less efficient. It would be interesting to undertake further research of other sectors to ascertain if these are an exception or the rule. Other public bodies or large institutions with extensive property portfolios could perhaps provide similar data to that afforded by Her Majesty's Court Service.

Her Majesty's Courts Service

In 2008 Her Majesty's Courts Service (HMCS) occupied 772 properties, one of the largest portfolios of any government department. 21% of HMCS buildings are pre-1900 and it had been assumed that the older buildings of their estate were the least energy efficient. However, research has shown that this is not the case (Wallsgrove, 2008). The research studied 33% of the HMCS building stock, studying buildings that had similar uses and occupancy profiles. The results showed a clear correlation between energy use per square metre and building age. Unexpectedly, the oldest buildings (pre-1900) use the lowest amount of energy (197kWh/m²) with those built immediately post-war (1940 to 1959) having the worst performance using 45 per cent more energy. Figure 24 shows the percentage energy use of HMCS's buildings according to age, taking the pre-1900 energy use as the datum. Even those buildings built 1990-2000, which one would assume have been built to achieve low carbon emissions, use 8% more energy than the pre-1900 buildings. The recommendations of the report were that the continuing use of historic buildings should be preferred over new construction.

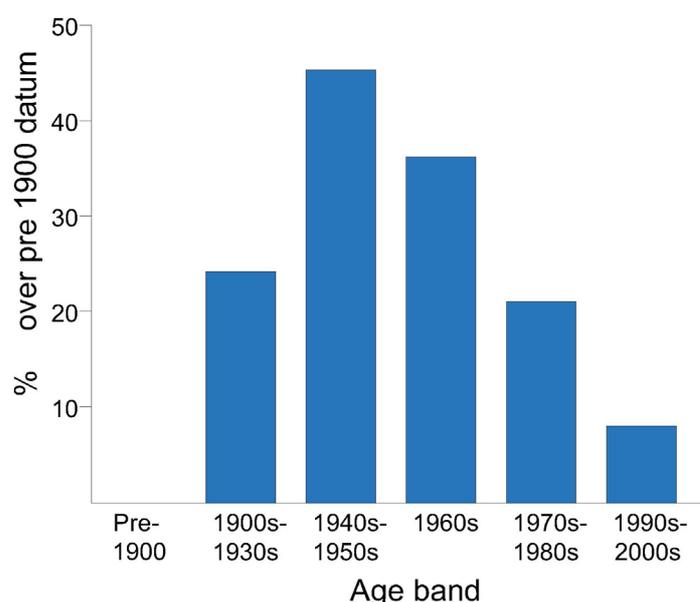


Figure 24 Percentage energy use of HMCS buildings over 1900 datum of 197kWh/m² (Wallsgrove, 2008)

Survey of energy use in museums

In the summer of 1991 a survey was undertaken of the energy use of 100 museum buildings in the UK (Oresrcryn et al., 1994). The sample aimed to be representational of all of the UK's museums with regards to collection type and floor area. The survey consisted of a questionnaire sent to both the museum directors and those most

responsible for the building's energy use. The survey achieved a 43% response rate, which reduces the reliability of the data, as does the inability of some respondents to provide accurate real energy use data. Notwithstanding, the results did show that on average energy accounted for 6% of the overall operational costs, with this ranging from 2% to 25% across the sample. Figure 25 shows a similar correlation between energy use and age as that seen in the research on the HMCS buildings. The oldest buildings appear to the left of the graph, i.e. with the lowest fuel costs. Conversely the newer buildings (save for the two newest) generally appear towards the right owing to their higher fuel costs.

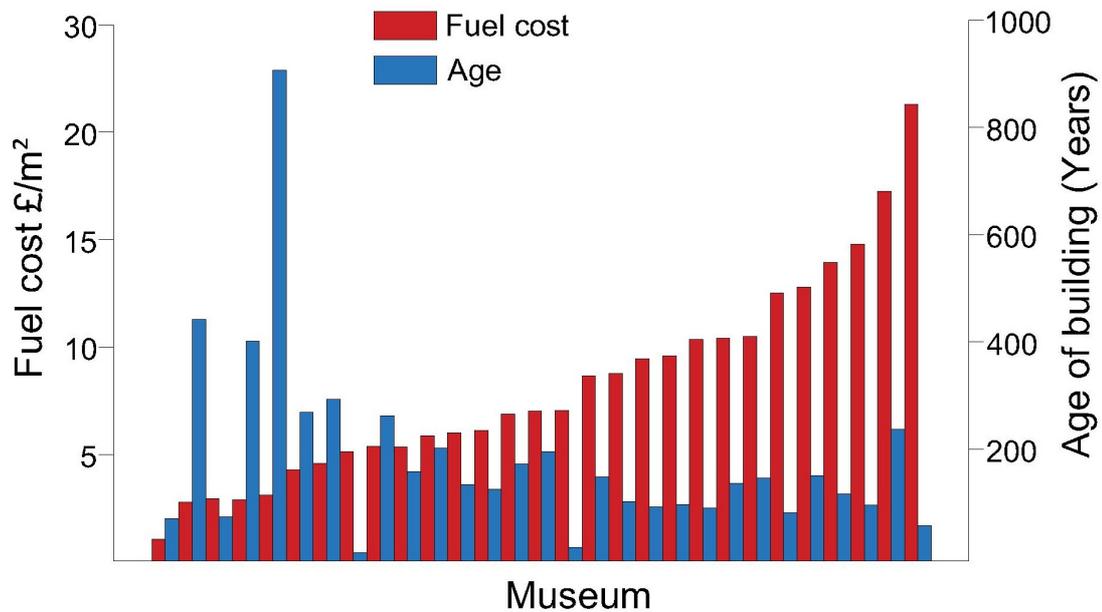


Figure 25 Age of museum listed in ascending order of annual fuel costs per m² (Oresrcryn et al., 1994)

Energy monitoring of Cardiff University's built estate

As part of the European Union iSERVcmb Concerted Action on Energy Performance of Buildings, the Welsh School of Architecture have been using smart metering to monitoring the energy use for Heating Ventilation and Cooling (HVAC) as well as lighting and electricity use of Cardiff University's entire property portfolio. Monitoring began in 2005 and is ongoing. The University's estate includes a wide range of typologies from teaching spaces, laboratories and residential properties, and consists of buildings from the very beginning of the 20th Century until the present. The information from this project provides an excellent opportunity to correlate this data with building age and condition.

Overall conclusions regarding availability and quality of existing data on the UK building stock, its age, composition and condition

There exists a sizeable amount of data with regards to the **quantity, age and typology** of both the domestic and the non-domestic building stock. Of all the data sources it is perhaps the designation lists that provide the most detailed information, although as noted this varies according to the listing officer. The challenge therefore is to obtain data regarding the **condition and energy performance** that can be correlated with that of age and typology.

The Housing Condition Surveys provide the best available information on the **condition** of the domestic building stock even though this is only for a limited sample. It is hoped that a new Welsh Housing Condition Survey will take place in the next few years, thereby allowing a review of concurrent data with that produced by England and Scotland. For England and Wales information from the Valuation Office Agency can offer an overview of the age of the non-domestic building stock, however, detailed information on individual buildings is not available, nor is information on condition.

The Buildings at Risk registers provide an overview of those listed properties in the worst condition. By 2018 The Handley Partnership's rolling survey of all 30,000 listed buildings in Wales should be completed. This will form an invaluable resource for studying the condition of the Welsh historic building stock. Similar schemes in England and Scotland could be considered.

It is perhaps **energy performance** that is the area most lacking in data. As discussed both SAP calculations and Energy Performance Certificates do not provide accurate data to correlate with age, typology and condition. In situ monitoring is therefore required of a representative sample, in conjunction with data on real energy use (bills) and calibrated simulation.

The following list suggests some possible future combinations of existing data with **new areas of study in bold**.

- Designation lists + Buildings at Risk Register (especially Cadw's) + **Energy Performance Monitoring**
- Housing condition surveys + **Energy Performance Monitoring**
- UCL's work on Building Stock in Camden + **Building Condition Surveys**
- **Review of condition and energy performance** of a specific sector, government agency or institutions with large property portfolio

10. Maintenance and energy performance

Whilst a lot of emphasis is placed on the role of maintenance with regard to preserving the built fabric of the historic environment, there is surprisingly little on the role that maintenance can play with regard to the energy performance of our buildings. This is perhaps due to a lack of sufficient research into this area. There exists a widely held belief that the two are connected but little empirical evidence as highlighted by the following quotes from the Technical Director of SPAB, Douglas Kent and the Director of Archimetrics, Cameron Scott and Director of BRE Wales & South West, Colin King.

“One figure that always seems a little contentious is the extent to which a damp wall loses more heat than a dry one - I've heard people quote 40% but others claim it's more like 30%” (Kent, 2016). “I think a study into the correlation between wall moisture and thermal performance is certainly one requiring some dedicated attention, I'm not sure there has been much done in this field and yet, ...there are various figures banded about. We [Archimetrics] have seen, what appears to be, this correlation but only as a 'likely explanation' for measured differences. Unfortunately, we don't have any data sets which will allow any robust analysis” (Scott, 2016). “...Yes the links between moisture and energy performance have figures bounced around with little evidence to robustly indicate one way or the other” (King, 2016).

Certain aspects of building degradation can affect the energy performance of the building through gaps, leading to higher air permeability, increased moisture content raising thermal conductivity, and the need for electric dehumidification (Forster et al., 2011). Although Forster et al. recognise that maintenance can reduce or retard the increase in energy use due to degradation, their analysis does not include this effect in their calculations, concentrating on the carbon emissions and energy consumption of the maintenance itself.

There has however been some research undertaken, most specifically into the correlation between moisture content and thermal conductivity of individual building materials. Studies have shown that the thermal conductivity of water saturated lime plaster is between three and four times higher than that of its dry state (Pavlík et al., 2009; Vejmelková et al., 2012). Although moisture content has a reduced impact on the thermal conductivity of less porous materials such as sandstone or fire bricks, there is still a notable increase between 0.9 and 2 times higher (Sugawara and Yoshizawa, 1962). For modern standardised construction materials, it is known that the coefficient of thermal conductivity or lambda (λ) of a material can be directly linked to its water content by the following equation:

$$\lambda(w) = \lambda_0(1 + b \cdot w / \lambda_s)$$

Where

$\lambda(w)$ [W/mK] = thermal conductivity of moist building material

λ_0 [W/mK] = thermal conductivity of dry building material

b [%/M.-%] = thermal conductivity supplement

w [Kg/m³] = total water content

λ_s [kg/m³] = bulk density of dry building material

The “supplement b indicates by how many percent the thermal conductivity increases per mass percent of building material, but in the case of hygroscopic materials, it is largely independent of their bulk density” (Künzel, 1995). This thermal conductivity supplement (b) has been measured for some common modern construction as shown in Table 3.

Building material	Bulk density (Kg/m ³)	Thermal conductivity (W/mK)	Moisture supplement –b (%/M.-%)
Cellular concrete	400-800	0.09-0.19	4
Lime silica brick	1800	0.7	8
Pumice concrete, expanded clay concrete	1400-1800	0.5-1.0	4
Light-weight concrete with ESP supplement	300-900	0.07-0.28	3
Normal concrete	2300	1.3-1.5	8
Wood	400-700	0.08-0.15	1.5
Expanded polystyrene foam (EPM)	15-30	0.04	0.05*
Extruded polystyrene foam (XPS)	28-40	0.03	0.1*
Polyurethane foam (PUR)	40-80	0.03	0.4*

* Values are valid only up to a water content of about 100 mass-%. In case of organic foam insulation, there is no linear relationship between thermal conductivity and water content

Table 3 Moisture supplement (in percent) in terms of the thermal conductivity of various modern building materials, related to the water content in mass percent – (after Achtziger et al., 1984)

The thermal conductivity supplement is also known for some historic and traditional construction materials as it is used in calculations within the software developed by the Fraunhofer Institute WUFI (Wärme Und Feuchte Instationär). It should however be noted that the databases utilized by this software contain only German, Austrian, North American, Japanese and Swedish materials and not all have thermal conductivity as a moisture dependant value. As most historic and traditional construction materials are based on local resources, their properties may well be different depending upon their geographical location. Further research is therefore required to determine the thermal conductivity supplement for British historic and traditional construction materials. It would appear that BRE have already undertaken some of this work, however, this information is not currently publically available and it is uncertain as to whether it will be in the future (King, 2016).

In this area, research has been undertaken for Historic England of the effect of moisture content on the thermal conductivity of three UK bricks. The tests demonstrated that the material characteristics (density and porosity) of the three samples of bricks (dry and wet) tested for thermal conductivity had an influence on the lambda value achieved. It also showed that the thermal conductivity of wet bricks was 1.5 to 3 times higher than that of dry bricks (Rhee-Duverne and Baker, 2013). The final report however recommended that both further tests of thermal conductivity for a range of moisture contents be undertaken and that “the effect of moisture on the U-value of traditionally constructed walls should be investigated and quantified” (Rhee-Duverne and Baker, 2013).

If a strong case could be made for the link between improved regular maintenance and energy efficiency then the emphasis could shift from not just caring for the built fabric but improved comfort and reduced energy bills. It is interesting to note that energy

saving opportunities identified by the assessment procedure of the UK Government's Energy Savings Opportunity Scheme (ESOS), which are compulsory for all businesses and charities that either employ more than 250 people or have a turnover in excess of €50 million and an annual balance sheet total in excess of €43 million (Environment Agency, 2015), include the maintenance of vehicles, industrial processes and building services (lighting and boilers) but not the maintenance of the building fabric itself (Environment Agency, 2015).

Building Bulletin 73 (DES, 1991) views maintenance and renewal of school buildings as an opportunity for the introduction of measures to improve energy efficiency. It does not however make the link between maintenance itself and energy use. Instead it advocates that energy efficient strategies can be introduced as part of the maintenance program at little or no additional cost when compared with replacement with like for like. The areas it focuses on are thermal insulation of the building envelope, improved airtightness and improved building systems. Local authority maintained schools consumed approximately 19,000 million kWh per annum in 1988/89 (DES, 1991).

The Churches Conservation Trust (CCT) cares for 346 churches (2013 figure) that have been closed for worship. In 1993 the CCT adopted a new strategy for its investment in the condition, repair and maintenance of the churches in their care. Pre-1993, repairs and maintenance were carried out on an ad hoc basis. Post-1993, a major capital investment repair programme was undertaken at the moment of taking responsibility of the church, addressing all urgent and non-urgent works, and an on-going maintenance regime was implemented. As might be expected, an analysis of expenditure showed that the post-1993 had higher upfront costs but lower costs overall if the building is held for a minimum of 9 years. However perhaps more interesting is that the utility bills for the post-1993 model over the period 2009-2015 were lower than those of the pre-1993 model (Historic England, 2015a). The final report recommends that "the CCT might find it helpful to explore why this decrease in utilities costs has come about" (Historic England, 2015a).

Overall conclusions regarding the correlation between maintenance and energy use

There still remains much work to be done with regard to the correlation between maintenance and energy use. If a clear connection could be made between the two, the case for continuing proactive maintenance would be strengthened. If maintenance was no longer a duty to protect our built heritage but became viewed as a way of improving comfort and lowering energy bills, then a greater proportion of historic building owners and users could be convinced of its benefits.

Some areas of potential research include:

- In situ measurements of u-values of external envelopes with varying moisture content – these need to take account of the complexity of in-situ measurements of moisture conductivity in composite walls as demonstrated by Brian Ridout.
- Laboratory testing of thermal conductivity of British historic and traditional construction materials at a range of moisture contents to define the thermal conductivity supplement (b).
- Review of energy performance of buildings that are part of proactive maintenance schemes, such as that of the CCT or Stirling's "Traditional Building Health Check", in

comparison to buildings only receiving reactive maintenance. This could include in situ monitoring, pressure testing and review of utility bills.

1.1. Traditional buildings, tenure and fuel poverty

Dwelling age and fuel poverty

The definition of fuel poverty has changed substantially within recent years, with DECC publishing a 2015 *Annual Fuel Poverty Statistics* report that introduced the concept of a 'low income high costs' definition of fuel poverty. This intends to move beyond the common '10% indicator', which defines fuel poverty as a situation in which "households are required to spend in excess of 10 per cent of their household income on heating and powering their home to a satisfactory standard" (Stockton and Campbell, 2011 p.4) The 'low income high costs' indicator consists of looking at the number of households that have both low incomes and high fuel costs and the depth of fuel poverty among these fuel poor households. This new 'depth' element of the indicator is measured using a "fuel poverty gap which represents the difference between the required fuel costs for each household and the median required fuel costs" (Department of Energy and Climate Change, 2015 p.9), as seen below in Figure 26.

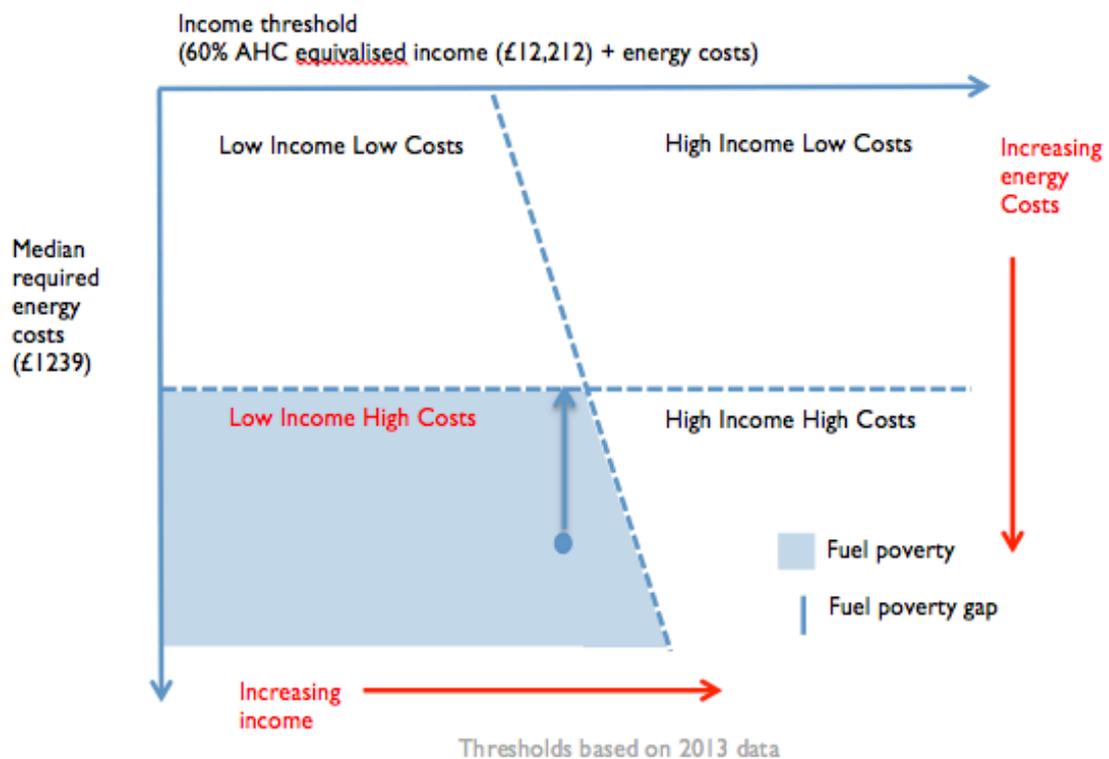


Figure 26 Fuel Poverty under the Low Income High Costs indicator (after figure 1.1 in DECC 2015 p.9)

Using UK-wide averages of both income and energy costs to ascertain the depth of fuel poverty gaps, the low income high costs indicator is a more nuanced approach to measuring fuel poverty which addresses some of the inherent variability in fuel poverty scenarios. However, inconsistencies exist in the use of the low income high costs indicator in devolved countries, with the low-income high-costs indicator only being

used in England. In Scotland, Wales and Northern Ireland still use the 10% indicator, meaning that a joined-up approach to tackling fuel poverty in traditional buildings is problematic. In practice, this means that discussions on the details of 'fuel poverty gaps' are limited to English cases. However, using both methods of measurement, there is a strong case for arguing for increased maintenance of traditional buildings. This is because of the relationship between dwelling age and the potential for fuel poverty. "Dwelling age is closely related to both the energy efficiency of the dwelling, and the floor area. Older properties tend to be less energy efficient and larger. We would, therefore, expect them to have higher fuel costs and be more likely to be fuel poor [...] households living in the oldest properties (those built before 1919) are more likely to be fuel poor than those living in more recent properties" (Department of Energy and Climate Change, 2015 p.38). These preconceptions require further study.

While DECC identify the probability of fuel poverty in pre-1919 buildings being higher than more recent post-1919 builds, independent analysis on fuel poverty by National Energy Action (National Energy Action, 2015) highlights the broader human and financial cost of fuel poverty across the UK. "Without adequate national and UK responses, between 2015-2030, NEA estimates that over 125,000 vulnerable people across the UK may die needlessly. Furthermore, national health services will need to spend billions treating cold-related morbidity, in excess of £22bn in England and Wales alone over the same 15 year period" (National Energy Action, 2015 p.4).

While energy efficiency improvements are seen as key to reducing both the energy costs and the carbon footprint of buildings, through targeting pre-1919 fuel poor homes a positive externality may arise in the form of indirect cost-savings for the NHS. Though this is typically very hard to quantify accurately, this aspect should be considered as part of the economic case for increased building maintenance, as the projected long-term costs of fuel poverty on the UK's NHS are severe. This is, however, according to a definition of maintenance that is tied up with improving energy efficiency in traditional buildings, rather than maintaining the current standard of energy efficiency or EPC rating. How exactly this is delivered, with the discrepancies in fuel poverty definitions noted above, is more complicated. National parliaments and assemblies could ensure more adequate support is granted to local authorities and local actors that have a more in-depth knowledge of local politics and the needs of local communities. As noted by the NEA report: "Local delivery partners are often best placed to tailor support to local needs and capture multiple benefits but need more adequate resource and support from national policy makers" (National Energy Action, 2015 p.4).

Therefore, stronger relationships may need to be formed with local authorities when thinking about how to increase building maintenance in traditional buildings that are also fuel poor households, for example, potential buildings within the National Heritage List of England. Within this context there could also be a greater role for local maintenance co-operatives and utilising their local knowledge and expertise to tackle fuel poor households in local communities.

Tenure

The makeup of tenure types in England is consistently changing, with the number of homeowners owning outright now outstripping those with a mortgage "since government records began in the early 1960s" (Department for Communities and Local Government, 2015 p.13). In England, there are three main tenure types; owner-

occupiers, private renters and social renters. Data from 2013-2014 shows that 'owner-occupation' was the largest of the three, with 14.3 million households alongside "4.4 million households in the private rented sector and 3.9 million households in the social rented sector" (Department for Communities and Local Government, 2015 p.17). It is important to note that among this demographic makeup, the responsibility for maintenance arrangements varies quite substantially according to tenure type.

Owner-occupiers are generally responsible for the upkeep of their own homes. Under private renting, the responsibility for maintenance falls under the remit of the landlord and not the tenants, and with social rented housing the maintenance arrangements will fall under the responsibilities of the local authority or housing association in question. When applying each different tenure type to the context of traditional pre-1919 buildings, the economic case or rationale for increased maintenance will vary according to the different stakeholders involved. So for example, while housing associations are not interested in making profits but rather "invest any surplus into the maintenance of their homes or building new ones" (Department for Communities and Local Government, 2015 p.21), owner-occupiers and private landlords may not necessarily use profits to enhance building maintenance or energy efficiency. This shows that the importance of tenure type in relation to increased maintenance cannot be overlooked.

Another issue to be considered is whether the owners have the leasehold or freehold on the property. While the majority of owners own the freehold to their home, a leaseholder will 'normally pay ground rent, an annual service charge and maintenance fees to the freeholder'. There are also examples of leaseholders owning a share of the freehold of a whole building. This means that responsibility for building maintenance "may include liability with others to repair and maintain the exterior of the building and the common parts" (Department for Communities and Local Government, 2015 p.19). These are both important when considering how to make the economic case for increased maintenance in traditional buildings, as this will inevitably result in increased costs. In relation to tenure type, it is important to identify where the costs will lie and with whom and also to consider the freehold and leasehold arrangements for maintenance.

Looking at devolved nations housing research sheds some light on further discrepancies and problems. Unfortunately, the most recent Welsh house condition survey took place in 2008. Therefore, it is unclear as to whether this data can be accurately cited in order to shed light on energy inefficiencies of traditional buildings, common tenure types and fuel poverty in Wales. It is suspected that some of the common problems with pre-1919 buildings will remain the same, and that both energy efficiency and fuel poverty concerns will be ubiquitous throughout traditional buildings in the Welsh housing stock. The Scottish Housing Survey is much more recent, looking more in depth at the relationship between fuel poverty and housing conditions (DHRW, 2015). The table below verifies much of DECC's (2015) assertions and asserts that pre-1919 buildings are responsible for the highest average modelled carbon emissions.

Dwelling Type	Dwelling Age		
	Pre-1919	1919-1982	Post-1982
Detached	15.3	11.1	9.2
Semi-detached	12.5	7.6	5.5
Terraced	12.2	6.4	5.5
Tenement	5.7	4.9	3.7
Other flats	7.8	4.9	3.8
All dwelling types	9.6	6.8	6.4

Table 4 Average Modelled Carbon Emissions (tonnes per year) by Dwelling Age and Type, 2013 (after Table 28 SHCS 2015 p.51)

The relationship that dwelling and type has to fuel poverty is also quite significant, as the survey notes that; “The lowest rate of fuel poverty is found in post-1982 dwellings. Less than one quarter, around 127,000 households, are fuel poor in these newer dwellings. Older dwellings in general have higher rates: 47% of households in pre-1919 dwellings are fuel poor” (DHRW, 2015 p.69).

Therefore, with regards to the maintenance of traditional buildings, tenure type is clearly a less important factor than dwelling age and type when it comes to identifying the prevalence of fuel poverty in pre-1919 builds. However, it is important to be considerate of tenure type in order for the responsibilities of maintenance to be identified, which will then enhance any strategy looking at tackling both fuel poverty and energy efficiency.

Limitations of retrofit

Research has demonstrated that retrofit measures do not necessarily achieve the outcomes envisaged through calculation or modelling. The BRE report commissioned by DECC and authored by researchers at the Welsh School of Architecture, Cardiff University, regarding thermal upgrades to solid walls concluded that inaccurate assumptions of performance, poor installation methods and changes in behavioural attitudes after thermal upgrades all contributed to the erroneous estimation of higher thermal performance (BRE, 2015). Recent work by Historic England and Glasgow Caledonian University at New Bolsover has highlighted issues relating to poor workmanship and a knowledge gap regarding traditional building materials. Weaknesses in manufacturing were highlighted by the poor seals in secondary glazing, windows made from new timbers rather than old, poor technical specifications from manufacturers as well as issues regarding occupant behaviour, for example, leaving windows open. The study also showed the limitations of modelling energy use, the discrepancy between steady state modelling and dynamic modelling. It also showed that modelling using SAP resulted in a greater calculated than measured heat loss (Rhee-Duverne, 2015).

The “Rebound Effect”

There is increasing concern about the effectiveness of energy efficiency upgrades in bringing about the level of savings in energy consumption these upgrades aim for. Jevons’ paradox or ‘backfire’ was first noted in 1865 with regard to the increasing use of coal with the advent of more efficient engines. *The Rebound Effect* whereby behavioural responses to energy efficiency improvements actually result in increased energy demand, was highlighted again in a report in 2007 which noted that: “In general, rebound effects have been neglected when assessing the potential impact of energy efficiency policies. A key conclusion of this report is that rebound effects are of sufficient importance to

merit explicit treatment. Failure to take account of rebound effects could contribute to shortfalls in the achievement of energy and climate policy goals" (Sorrell, S, 2007 p.7). These conclusions have been upheld in more recent work. Savings are frequently found, in practice, to be less than those predicted in calculations, and the shortfall is often discussed under the heading of the 'rebound effect' (Galvin, 2014 p.1). Whilst behavioural analysis will fall beyond the scope of this research, it is important to remain aware of this work and that there is potential to correlate such studies more closely to the perceived benefits of retrofit to traditional building stock.

Sunikka-Blank and Galvin have coined the term 'prebound' to define the misconstrued thermal performance of existing built fabric prior to retrofitting (BRE, 2015). They describe how the combined effects of 'prebound' and 'rebound' can impact upon actual energy savings (Sunikka-Blank and Galvin, 2012). As noted above, the importance of developing significant databases of in situ measurements should not be underestimated. It may be possible for researchers to develop considerations regarding the less engineered and more engaged potential for maintenance activity to inform or change behaviour with regard to energy use.

The need to revise assumptions

The Standard Assessment Procedure and Reduced Standard Assessment Procedure, SAP and RdSAP, the Government tools for the estimation of energy use in new and existing buildings respectively, were designed to provide a unified approach. As has been noted by many, historic buildings require more accuracy if they are to be assessed fairly (BRE, 2015). It is possible to collate data which record actual energy consumption as opposed to assumed energy use. Records made through the EU-funded iSERVcmb project at Cardiff University have demonstrated that energy use profiles are not necessarily related to building or construction type or even to room use but much more closely to user profiles. It is possible that the programme run here could be applied to existing data from other estates and that further data such as condition could be added to this suite.

12. Proactive maintenance schemes

The results of the "Survey of Listed Building Owners" showed that the majority of those who responded to the survey undertook all the listed types of repairs and maintenance periodically (Murray et al., 2015). It should however be noted that the response rate to the survey was only 9.5% and one could suppose that those historic building owners who are conscientious enough to respond to a survey would also be responsible enough to ensure regular maintenance, and so therefore this may not fully reflect the true picture of maintenance of historic buildings in England. That said the survey did show that over 50% of those who responded cleaned gutters, downpipes and drain covers, and checked roof coverings, flashings and chimneys at least once a year (Murray et al., 2015) whereas painting and repairs of walls, windows and doors tended to be on a longer cycle of every 2-5 years or even 6-10 years.

There follows a summary of national and international schemes which aim to be proactive rather than reactive with regards to maintenance of historic buildings.

	Scheme	Scope	Limitations
Places of Worship	Diocese of London Gutter Maintenance Programme.	Gutter cleaning scheme for Church of England churches within the Diocese of London. Running since 2006	Limited to Church of England churches. Only focuses on gutters and drains, although these are a key item in church maintenance.
	Gutter Clear	Gutter cleaning scheme by the Diocese of Gloucester now in its 4 th year. All places of worship, of all faiths and denominations can join.	Limited to places of worship. Only focuses on gutters and drains, although these are a key item in church maintenance.
	ELIX	Diocese of St Edmundsbury and Ipswich. Non-denominational.	Limited to Christian places of worship. Only focuses on gutters and drains, although these are a key item in church maintenance.
	Maintenance Co-operatives, SPAB	A network of English volunteer groups undertaking "a programme of planned preventative maintenance" on places of worship.	Limited to places of worship
	Faith in Maintenance, SPAB	Training for those maintaining places of worship.	
	Churches Conservation Trust	Cares for 346 churches that have been closed for worship. Adopted a more proactive approach to maintenance in 1993. A report published 2013 showed lower costs overall if building held for a minimum of 9 years.	A comparison of pre and post-1993 utility bills showed a saving. Further research in this area is recommended.

	Scheme	Scope	Limitations
International Schemes	Monumentenwacht Netherlands	Originated in the early 1970s. Now one of the largest in the Netherlands involved in the care of historic buildings. Separate schemes operate in Groningen, Friesland, Drenthe, Overijssel en Flevoland, Gelderland, Utrecht, Noord-Holland, Zuid-Holland, Zeeland, Noord-Brabant.	
	Monumentenwacht Flanders, Belgium	An initiative of the King Baudouin Foundation, the Foundation for the Conservation of Monuments and Landscapes and the Flemish Association of Provinces. It was set up in September 1991.	
	Raadvads Bygningssyn	Danish historic building maintenance inspection service offered by the Centre for Building Preservation a private organisation encouraged by the Danish Cultural Agency.	
British Initiatives	Maintain our Heritage	Bath Pilot Scheme: From 2002-2003 MoH undertook a pilot scheme for a historic building maintenance inspection service in Bath.	Although the target of 72 buildings was exceeded, the take up rate was not sufficient to make it commercially viable. Perhaps due to the limited geographical scale.

	Traditional Building Health Check	Stirling City Heritage Trust. 5 year Pilot scheme, started 2013 for pre-1919 buildings in Stirling.	Results for the first 5 years should be available in 2018. Appears not to make a strong link between proactive maintenance and energy use.
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Table 5 Summary of national and international proactive maintenance scheme

Proactive maintenance schemes for places of worship

Gutter Clear <http://www.gutterclear.org/> Gutter cleaning scheme by the Diocese of Gloucester now in its 4th year. The diocese has an accredited list of contractors who can be contracted to do regular work on a prearranged cyclical basis. Similar schemes are in place in the Diocese of St Edmundsbury and Ipswich (**ELIX** http://www.cofesuffolk.org/uploads/dac/Elix_2_Brochure_v2-1.pdf), Chelmsford, (**Gutter Clearance Scheme** <http://www.chelmsford.anglican.org/parishes/dac/gutter-clearance>) and London (**The Gutter Maintenance Programme** <http://www.london.anglican.org/kb/gutter-maintenance-programme/>). “The Diocese of London found that if a church doesn’t clear out its gutters for five years, (which costs about £250 a year plus VAT), the resulting repair bill is never less than £25,000 and often a lot more” (Maintain our Heritage, 2011).

Maintenance Co-operatives, SPAB <http://www.spabmcp.org.uk/>. A network of English volunteer groups undertaking “a programme of planned preventative maintenance” on places of worship. SPAB also offers training for those maintaining places of worship through their **Faith in Maintenance** programme (http://www.spabfim.org.uk/pages/project_aims.html) which continues to be made possible by some part-funding they received from Historic England in 2012. In addition to these schemes which focus exclusively on religious buildings, SPAB also organises the **National Maintenance Week** (<http://www.maintainyourbuilding.org.uk/index.php>). The last event took place the week beginning 20th November 2015 and focused on the importance of winter maintenance.

International schemes

Monumentenwacht Netherlands and Flanders

A very good overview of both the Dutch and Flemish Monumentenwacht is given by the report prepared by the Stirling City Heritage Trust (Stirling City Heritage Trust, 2012).

The Dutch scheme originated in the early 1970s and has now grown to be one of the largest in the Netherlands involved in the care of historic buildings. It is an independent not-for-profit organisation. Its fundamental principles are expertise, impartiality and independence. A national umbrella organisation encompasses 11 provincial organisations. The majority of the work takes place at the level of the provincial organisations.

Their websites are:

Groningen: www.monumentenwacht groningen.nl

Friesland: www.monumentenwacht-fryslan.nl

Drenthe: www.monumentenwacht-drenthe.nl

Overijssel en Flevoland: www.monumentenwacht-ovfl.nl

Gelderland: www.monumentenwacht-gld.nl

Utrecht: www.monumentenwacht-utrecht.nl

Noord-Holland: www.monumentenwachtnoordholland.nl

Zuid-Holland: www.erfgoedhuis-zh.nl

Zeeland: www.scez.nl

Noord-Brabant: www.mwnb.nl

Limburg: www.monumentenwachtlimburg.nl

These organisations undertake inspections, provide advice and act as the immediate point of contact with the historic building owners. The core idea behind the scheme is that proactive maintenance is far more effective and efficient than reactive maintenance.

“Awareness has also grown among politicians: systematic maintenance always means substantial savings in restoration costs. While twenty years ago the focus was almost entirely on restoration, now politicians realise that expensive restoration work can only have an effect if systematic and preventative maintenance is done as well.” (Stirling City Heritage Trust, 2012)

Whilst there is this claim that there is a financial benefit, there does not appear to be empirical evidence of this. A new publication by researchers at TU Delft looks at the benefits of the “Monumentenwacht” system and aims to analyse if this system contributes to a better and more cost effective conservation of the Dutch built heritage (Hees et al., 2015). The study concludes that the biggest benefit is the early detection of potentially major problems, thereby allowing timely preventative maintenance. As a result the historic building stock in the Noord-Brabant region (the region under study) is in a better condition. It goes on to state that there are cost savings for building owners, insurers and policy makers but it does not pretend to quantify these savings in exact financial numbers. Another financial benefit mentioned but not quantified is the generation of employment that arises from the scheme (Hees et al., 2015).

The Flemish scheme follows the model of the Dutch Monumentenwacht and was set up in 1991 as a reaction to the Granada Convention (Council of Europe, 1985). Its website is <http://www.monumentenwacht.be/>. The scheme is an initiative of the King Baudouin Foundation, the Foundation for the Conservation of Monuments and Landscapes and the Flemish Association of Provinces.

Raadvads Bygningssyn

Raadvads Bygningssyn <http://www.bygningsbevaring.dk/bygningssyn> is a Danish historic building maintenance inspection service offered by the Centre for Building Preservation, a private organisation encouraged by the Danish Cultural Agency. The methodology of the scheme involves quinquennial inspections, reports and maintenance plans. The scheme also offers reduced services and even offers a site inspection and verbal advice with no written report.

British initiatives

Maintain our Heritage

Maintain our Heritage (MoH) <http://www.maintainourheritage.co.uk/> is a not for profit organisation which originated from a conference held by the Bath Preservation Trust in 1998 to coincide with the 25th anniversary of the Dutch Monumentwacht. From 2002-2003 MoH undertook a pilot scheme in Bath for a historic building maintenance inspection service. The conclusion of the pilot was that although the target number of 72 buildings was exceeded, the take-up rate was not sufficient to make it a commercially viable. The limited geographical scale of the pilot was cited as a possible reason for this lack of economic viability (Maintain our Heritage, 2003).

In 2004 MoH published the findings of their research programme “Maintaining Value” (Maintain our Heritage, 2004). The research was financed by the Department of Trade and Industry (DTI) (through Partners in Innovation), English Heritage (as was) and Heritage Lottery Fund with contributions also from CITB-Construction Skills and University of the West of England. The research was undertaken by the University of the West of England, Arup- Research + Development and De Monfort Expertise Ltd. The recommendations of the report were that UK should work towards a UK Strategy for Maintenance; that legislation should be changed to introduce a statutory duty of care or allow local authorities to implement a minimum maintenance code; that current historic building enforcement powers should be reviewed; the development and dissemination of best practice; that financial aid should be made available; and that further research was required into demonstrating the costs and value of maintenance tasks. The areas covered by the research project were current best practice in the UK and Europe, individual owners’ approaches, commercial maintenance services, supply and demand, the business case for planned maintenance, and the availability of technologies and trained workforce. The finding of this report should be revisited to understand how the situation has changed over the past 10 years.

Traditional building health check

The call for a Scottish “Monument Watch” by the Stirling City Heritage Trust proposed a national proactive maintenance scheme along the lines of the Dutch and Flemish Monumentwacht (Stirling City Heritage Trust, 2012). Following an in depth study of international and national precedents, a 5 year pilot scheme was established on 1st April 2013, the “Traditional Building Health Check”. The pilot is being managed by Stirling City Heritage Trust in partnership with Historic Scotland, with support from the Construction Industry Training Board <http://conservation.historic-scotland.gov.uk/healthcheckscheme>. The scheme is open to owners of pre-1919 buildings in Stirling <http://traditionalbuildingshealthcheck.org/> for an annual membership of between £22-£45 depending on the property, members receive access to a subsidised external building fabric inspection which is then followed by advice on necessary repairs and a proactive maintenance programme.

In the report “A Scottish Monument Watch” (Stirling City Heritage Trust, 2012) that presented the findings of their study and the proposals for a Scottish scheme, links between building maintenance and energy efficiency go no further than suggesting that good maintenance is essential when insulating (Stirling City Heritage Trust, 2012). The report also questions if insulating solid masonry walls is advisable.

Overall conclusions regarding the precedents for proactive maintenance schemes

The sector where most has already been done with regard to proactive maintenance is for places of worship. These types of schemes should be applied to other building typologies. Undoubtedly the Stirling pilot “Traditional Building Health Check” is at the vanguard of applying the methodology of the international precedents to a UK context. The outcome of this study is eagerly awaited when the projects initial pilot phase is completed in 2018. It would also be interesting to study the effects on the buildings’ energy performance that arise from the new approach. Equally the recently published book on the effectiveness of Monumentenwacht should be obtained and studied, even if it does not quantify the importance of the system in exact financial numbers.

13. Strengthening incentives for maintenance

Incentives and drivers

12 years ago *Maintain our Heritage* highlighted that owners are motivated by convenience, not conservation (*Maintain our Heritage*, 2004). It also recommended that best practice and maintenance-focused grants should be implemented by Cadw, Historic Environment Scotland and Historic England in an effort to consolidate a UK-wide strategy for maintenance. There is already evidence to suggest that there are close ties to be connected in current thinking across governmental and industrial sectors. The 2016 Select Committee report: *Building Better Places* contains a range of recommendations designed to improve the way national policy is developed and implemented in the built environment, including design quality, sustainability, housing and professional skills.

- Point 180: “England lacks a proactive, long-term national strategy for managing our historic environment, as part of planning for the future of the built environment. We believe that such a strategy, which would recognise the full value of our built heritage as a unique national and local asset, central to place-making, should be articulated for the future.”
- Point 184: “The maintenance and upkeep of buildings of historic value can have a significant impact upon the sense of pride and pleasure that a community feels in its surroundings; we were told that the historic environment has a significant role to play in identity and place-making. At the same time, our evidence consistently identified some of the difficulties in maintaining historic buildings and maximising the use of heritage assets.”
- Point 187: “At present, VAT is charged at a rate of 20% on repairs and maintenance to existing buildings, while VAT on much new-build construction is zero-rated. This provides a perverse disincentive to the retention, restoration and revitalisation of historic buildings, and works to prevent owners from looking after them properly. We recommend that the Government should review the rates of VAT charged on repairs to listed buildings, and examine the economic rationale for reducing the rate.” (Select Committee on National Policy for the Built Environment, 2015-16)

The cost benefits of maintenance are noted. *Maintaining Value* noted the potential for inspection based insurance policies to reduce premiums based on good maintenance (Maintain our Heritage, 2003 v.5 p.14). *The Economic Impact of Maintaining and Repairing Historic Buildings in England* report commissioned by the HLF and Historic England noted that whilst largely reliant on the private sector, public funding often acts as an enabler “unlocking the scale of economic benefits embodied in built heritage assets” (Ecorys, 2012). It is the viability of these incentives and motivational tools that future research should address. Incentives for better maintenance are clearly driven by investment duration, the council of mortgage lenders estimate that homes currently change hands every 23 years whilst the rate was only every 8 years in the 1980s (Frank, 2015).

In terms of landlords’ incentives, the “Decent Homes Standard” was introduced in 2000 to underpin the “Decent Homes Programme”. In 2006, the Housing Health and Safety Rating System (HHSRS) was introduced in line with the Housing Act 2004 and the Decent Homes Standard definition was updated (DCLG, 2006). Private landlords are now encouraged to be trained and registered through discretionary schemes in England and compulsory provision in Wales. The minimum energy performance rating of E on an Energy Performance Certificate (EPC) for rental properties from the 1st April 2018 will only apply to unlisted properties, however, it will affect many traditional unlisted buildings.

It is important to examine the potential value of this work to wider stakeholders such as health, property and insurance organisations. It is equally important to consider the potential of incorporating the data resources which have recorded perceived levels of phenomena such as urban degradation related to perceived crime risk or health related data which may be related to poor levels of building maintenance.

Highlighting risks

The 2013 Skills Needs Analysis noted a perceived reduction in grant funding during the recession: “There is a perception of diminished grant funding for repair and maintenance, and perceived administrative burdens and/or onerous requirements associated with grant application processes, which can prevent applications for funding.” (Pye Tait, 2013 p.11). It also highlighted the introduction of a ‘notice of liability’ to be charged to a property owner in Scotland for urgent works (Planning (Listed Buildings and Conservation Areas) (Scotland) Act, 1997). It has been noted anecdotally that around 80% of home owners are underinsured, by an average of around 45% (Tufton, 2013). The Institute of Historic Building Conservation (IHBC) noted that a key reason for around 20% of household insurance claims being rejected was “wear and tear or damage caused by a lack of maintenance which are not insurable” (IHBC NewsBlog, 2016). The efficacy of such evidence in persuading people to act requires monitoring.

Climate change and regional risk

After the Paris Climate Change Summit 2015, Matt Cullen, Head of Strategy at the Association of British Insurers said: “The increased frequency and severity of major weather events means insurers are at the forefront of witnessing the real impacts of climate change. Storm Desmond is a stark reminder of this, and insurers’ role to help people be resilient to climate impacts. Insurers also have a critical role to play in helping to support the transition to a low carbon world through sustainable investments and through insuring renewable energy and energy efficient homes. Insurers are already

pursuing policies with an aim of reducing climate impact and they will do much more, alongside governments and other industries” (Cullen, 2015).

In 2009, in a summary of the anticipated effects of climate change in presentation to the Historic Houses Association, an exaggeration of the north-south UK ‘divide’ especially in terms of moisture risk was identified:

- Increased soil moisture, flooding, soil waterlogging in north and west
- Increased drought and soil shrinkage/cracking in south and east
- Climate change will be one of several increased stresses on buildings, landscape and wildlife, often with multiplying effect
- Adaptation will be important (Parry, 2009).

Maintain Our Heritage in 2004 recommended that the Buildings at Risk register could be used as a management tool (Maintain our Heritage, 2004). To some extent fire services have been using methods that might compliment that approach (Government, 2008). Web-based interactive maps such as MagicMap should be enlarged to include Scotland, Wales and Northern Ireland. This can help to correlate the location of heritage assets and environmental risk (The Handley Partnership, 2013).

The business case for maintenance

The Ecorys report: *The Economic Impact of Maintaining and Repairing Historic Buildings in England* concluded that the built heritage construction sector contributed £12.5bn of the UK GDP as a whole (Ecorys, 2012)p.15. Maintain our Heritage noted that it is difficult to prove the economic value of an activity that is preventative (Maintain our Heritage, 2003) v5, p.24. This question of quantification is a critical driver for future research. The proverb of the SPAB ‘stitch in time’ can appear nebulous. Different stakeholders require different justifications.

The economic impact of the built heritage construction sector in England is closely correlated to economic wealth and property value (Ecorys, 2012 p.10). How this correlates to the number of historic buildings should be clarified. The same report indicates that the relative impact of the sector in Scotland, Northern Ireland and Wales, however, the percentage impacts between them (of GDP in aggregate) cannot easily be identified and this would be a useful determining issue. Also were the data to be regionally disaggregated within each, as for England, further insights could be made.

The 4,865,000 pre-1919 buildings England which are domestic outnumber the 552,000 non-domestic ones by almost 90% according to Ecorys’ estimation (Ecorys, 2012). They argue that we need more data on non-domestic buildings and the proportion that are listed: “Available Valuation Office Agency (VOA)/ Department for Communities and Local Government (DCLG) data would tend to confirm this view, suggesting that in the order of one-half (51%) of the commercial and industrial stock in England is comprised of pre-1940 buildings (the proportion that relates to pre-1919 buildings is not known)”(Ecorys, 2012 p.7).

	Total Output (£m)	Total Employment (FTE)	Total GDP (£m)
South West	2,296	44,191	983
South East	5,048	97,148	2,162
London	4,515	86,898	1,934
East	3,282	63,163	1,406
East Midlands	1,852	35,640	793
West Midlands	2,345	45,129	1,004
Yorkshire & Humber	2,509	48,296	1,705
North West	2,899	55,799	1,242
North East	857	16,492	367
England	25,603	492,757	10,965

Source: Ecorys analysis. N.B. sum may not add up to the total due to rounding.

Table 6 Built Heritage Construction Sector: Total Economic Impacts (English Regions Source: (Ecorys, 2012 p.10)

International models for shared maintenance

In France in 2000, 20% of all dwellings were flats in co-ownership schemes and a legal framework of co-ownership, *copropriété* is established there. For in the USA and Canada condominiums, and in Scotland legal frameworks for flat ownership are derived from the common-law notion of Tenement (Cole and Robinson, 2000 p.595-6). Strata Title, developed in Australia, forms the basis for models in Indonesia, South Africa, Singapore, Malaysia and New Zealand (Dredge and Coiacetto, 2011). These systems of tenure have been adapted and used all over the world, providing a significant body of experience to draw upon. Webster and Le Goix emphasise the likelihood of privatised commonhold systems of tenure becoming more prevalent globally (Webster et al., 2005). In the UK however, although the Commonhold and Leasehold Reform Act 2002 introduced commonhold ownership in England and Wales, very few developments have taken this up.

Forms of legal ownership are very varied and the impact of numerous stakeholders including lenders, insurers and agents present often conflicting concerns (Lemberg, 1979 p.704-5). Van der Merwe's comparative discussion of the development of legal provisions for shared ownership internationally noted a distinction between systems that envisaged maintenance as a right or a duty and the complexity of shared or individual provisions for structural or servicing elements of the building (Van der Merwe, 2002). Yip points out that whereas co-operatives enable inhabitants to lease from a jointly owned stake, condominiums enable residents to purchase individual units but makes the ownership of and responsibility for shared areas less direct (Yip and Forrest, 2002 p.706). In the vastly different but challenging developmental economic context of Hong Kong the *Revitalising Historic Buildings Through Partnership Scheme* has succeeded in engaging the support of existing tenants and the government landlord in co-ordinating a preservation plan that retained the existing trades in situ. Such arrangements are obviously closely related to the economic conditions of the context and the extent of work required. The potential for co-ownership schemes which champion maintenance internationally should be evaluated in the context of collectively inhabited but not co-owned structures such as terraced houses in the UK.

International models for skills development

A number of projects internationally have sought to address issues arising in historic areas with poor living conditions aiming to enable people to remain in their historic districts during significant periods of economic change (should they wish it). Fan has observed a tendency for top-down processes in China and a predilection for using heritage as an economic resource over residents' interests (Fan, 2013), citing an instance where residents were relocated in the old town of Yangzhou. A more recent example in Hong Kong, "the blue house cluster" (Commissioner, 2014), has recently succeeded in maintaining its trade tenants in lieu of re-furbishing the domestic parts of the block.

The potential for self-management to be a positive step in a renewal process has been established (Wekerle et al., 1980). A study in 1987 observing maintenance in low income condominiums noted a strong correlation between social cohesion and maintenance, concluding that self-management was less expensive and more effective. The paper found that renewal policies that encouraged residents' involvement through Building Committees of unpaid elected residents in their management had a significant impact on the quality of subsequent maintenance (Werczberger and Ginsberg, 1987).

It is notable in reviewing literature on the subject that whilst the complexity of the architect's work in the refurbishment of historic shared residential buildings was acknowledged in the 1970's (Lemberg, 1979), the trend of heritage management rhetoric towards the community to some extent eclipses mention of the need for qualified input. Yet a study in Malaysia (Muhamad Ariff and Davies, 2011) has highlighted the need for professional advice to be made available to Maintenance Committees. Here the example of the Parisian *Compagnie des Architectes de copropriété* (Compagnie, 2014) is particularly relevant. A list of architects offering specifically accredited conservation skills is offered to historic co-owned buildings in Paris. This framework is part of a wider governmental support network for heritage skills and crafts which also supports the development of trade and skills through the guild based apprenticeship schemes of *Les Compagnons du Devoir* (Les Compagnons du Devoir, 2016) and state-founded *l'Institut Supérieur des Métiers* (ISM, 2016) as well as products through the state label of living heritage founded in 2005 *La Commission nationale des Entreprises du Patrimoine Vivant* (EPV, 2016).

Skills and capacity in the UK

A number of studies investigating the business case for maintenance of heritage buildings have focussed on the workforce and skills capacity of the UK. A key finding of the 2013 *Skills Needs Analysis* was that the recession had caused much non-essential work to be postponed, risking longer term damage to buildings (Pye Tait, 2013 p.11) it also identified that the cost of using traditional building materials was still seen as a barrier although awareness was increasing. It recommended that proactive repair work was promoted, including promoting public awareness of tools, materials and skills as well as appropriate approaches to energy efficiency retrofit. It did not identify the correlation between better maintenance and energy efficiency specifically but made a recommendation to raise stockholder awareness of the energy efficiency benefits created through carrying out repairs and undertaking regular maintenance of their buildings.

The 2003 *Maintain Our Heritage* study "Maintaining Value" carried out a SWOT analysis of the business case for maintenance noted the networking potential for business relationships and cash flow stability through long term maintenance

programmes (Maintain our Heritage, 2003). On the basis that 80% of listed buildings in England are privately owned, it focussed on this group. However it also noted that heritage home owners were more affluent and used this as a positive – this presumption was based on a UWE survey that surmising that the “average” profile of building was detached and valued between £351 and £500,000, in villages and owned by relatively well educated and affluent people. More recent data from the Survey of Listed Buildings Owners appears to affirm this trend in England (Murray et al., 2015). This profile should be challenged by future research which aims to broaden the category of stewardship stakeholders.

The Skills Needs Analysis report uses the housing condition surveys to determine that 77% were suffering from disrepair to critical elements (Scotland, 2011) and goes on to schedule workforce demand in both England and Scotland (Pye Tait, 2013) p.33. The report also demonstrates the magnitude of the repair and maintenance market share. (Pye Tait, 2013 p.44).

Business models review

Maintain our Heritage ran models with fixed price inspections, inspections on two tiers and inspections with additional work (modelled on the car industry). It sought to set out the frequency of various tasks against costs (Maintain our Heritage, 2003 v.5 p.16). The frequency of attendance to various aspects of maintenance is surveyed in The Survey of Listed Buildings Owners (England) (Murray et al., 2015).

Maintaining Value noted that the Bath pilot had a 10% take up rate and even the heavily subsidised *Monumentenwacht* had only a 50% take up rate (Maintain our Heritage, 2003 v.5 p.15). This raises the question as to how such incentives, were they widely available, might be made more successful. The most recent Survey of Listed Buildings Owners recommended that the heritage sector step up in provision of both advice on energy efficiency improvements and signposting for maintenance strategies (Murray et al., 2015).

A wider business model would clearly take into account broader factors affecting a wider range of stakeholders. In addition to owners and occupiers, the construction industry and heritage agencies these would also include other commercial and governmental bodies. The adoption of a risk related approach to quantifying the potential impact of neglect incorporates the interests of insurers and mortgage lenders but also implicates broader correlations to agencies responsible for health and well-being.

14. Conclusions

Gaps in data

Listings

- Further research should be undertaken to establish an approximation of the number of unlisted pre-1919 properties.
- The quality of the descriptions varies dramatically.
- The designation lists have a huge amount of useful data that can be analysed with collaboration.

Domestic and non-domestic building stock

- In general there is more detailed information regarding the age and condition of the domestic stock than there is regarding the non-domestic stock.
- For all surveys it should be noted that the age of the building is based on an estimate by the householder and/or the interviewer and not on accurate historic data. The English Housing survey shows that in England 20% of the dwelling stock was built pre-1919 but the conclusion is based on this method of appraisal.
- If the Valuation Office in England and the Scottish Assessors Association made public their data, this could be very useful for assessing the condition of the non-domestic building stock in England and Wales.
- Overall, in 1998, 45% of non-domestic buildings were pre-1919 and 25% of the non-domestic floor area. Given the construction of new buildings and demolition of old over the past 18 years, these figures are unlikely to still be an accurate representation. A review of current data is therefore required.

Energy data

- Energy efficiency data included in the housing surveys is flawed being based on SAP (Standard Assessment Procedure) calculations and not measured energy use.
- Older buildings are assumed to be less efficient, as are detached properties due to their increased surface to volume ratio. This highlights the need for measured energy data, or simulation based on measured variables and not preconceived assumptions.
- There is evidence to suggest inaccuracies in the dating of the buildings for non-domestic stock.
- The challenge is to obtain data regarding the condition and energy performance that can be correlated with that of age and typology.

New data is required to correlate

- Designation lists + Buildings at Risk Register (especially Cadw's) + Energy Performance Monitoring
- Housing condition surveys + Energy Performance Monitoring
- UCL's work on Building Stock in Camden + Building Condition Surveys
- Review of condition and energy performance of a specific sector, government agency or institutions with large property portfolio

Questions for further research

- A survey of the condition of listed buildings in Wales shows an increase in disrepair as the listing grade decreases, with Grade I buildings being in the best condition. Could it be assumed that this trend would continue if non-listed pre-1919 buildings were included? This requires verifying.
- A map of Scottish Buildings at Risk shows that the highest number of buildings at risk can be found in Aberdeenshire with 271 properties, closely followed by Argyll and Bute with 235. These statistics should be correlated against other indicators such as wealth, building type and building age.
- The results from surveys of courts and museums challenge common assumptions that older buildings are less efficient. Further research of other sectors should be undertaken to ascertain if these are an exception or the rule.
- Further research is required to determine the thermal conductivity supplement for British historic and traditional construction materials.

- Further research is required to demonstrate the efficacy of maintenance in energy reduction.
- Further research is required to explore behavioural responses to maintenance programmes and how stewardship in relation to tenure and collective responsibility can be incentivised.

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